13 APPENDICES

13.1 APPENDIX 1 - LAND COVER PERCENTAGES

Tables to summarize land ownership by cover types, Table 1 and Table2.

Table 1. Percent Land Owner/Type per Cover Type

Cover Type Group	B.L.M.	Bureau of Indian Affairs	Department of Energy	Forest Service	Military Reservations	National Parks & Monuments	Open water	Private	State of Idaho	U.S. Fish & Wildlife Service	Grand Total
Agricultural crop and pastureland	4.4%	1.3%	0.1%	0.4%	0.0%	0.0%	0.4%	**92.2%**	1.1%	0.1%	100%
Alpine	0.3%	0.0%	0.0%	**99.3%**	0.0%	0.0%	0.3%	0.2%	0.0%	0.0%	100%
Annual grasslands	**64.3%**	0.0%	0.2%	0.1%	2.4%	0.0%	0.2%	**26.9%**	5.9%	0.1%	100%
Foothills and Plains Woodlands	**58.1%**	0.0%	1.3%	**15.8%**	0.0%	2.2%	0.3%	**15.0%**	7.2%	0.1%	100%
Montane Forests	2.0%	0.2%	0.0%	**72.6%**	0.1%	0.0%	0.1%	**19.5%**	5.5%	0.0%	100%
Montane Forest-Steppe Transitions	**10.3%**	0.9%	0.0%	**66.1%**	0.1%	0.0%	0.1%	**17.5%**	5.1%	0.0%	100%
Montane Shrub fields	**14.5%**	0.1%	0.0%	**57.8%**	0.0%	0.0%	0.4%	**20.1%**	7.2%	0.0%	100%
Perennial bunchgrass seedings	**78.3%**	0.0%	0.6%	0.4%	4.4%	0.3%	0.0%	**10.6%**	4.8%	0.6%	100%
Recent timber harvest areas	0.3%	0.0%	0.0%	**59.7%**	0.1%	0.0%	0.0%	**29.4%**	**10.5%**	0.0%	100%
Riparian and Wetland Types	2.5%	2.3%	0.0%	5.6%	0.0%	0.1%	**56.7%**	**24.4%**	1.9%	6.3%	100%
Shrub Steppe and Grasslands	**59.0%**	2.4%	3.8%	6.1%	0.1%	0.3%	0.2%	**20.9%**	7.0%	0.0%	100%
Sub alpine Forests	1.1%	0.0%	0.0%	**94.6%**	0.0%	1.2%	0.1%	2.3%	0.7%	0.0%	100%
Sub alpine Parklands	0.4%	0.0%	0.0%	**94.3%**	0.0%	0.0%	0.2%	1.2%	3.9%	0.0%	100%
Urban and Industrial	1.4%	0.0%	0.0%	0.2%	1.7%	0.0%	2.0%	**94.4%**	0.2%	0.0%	100%

Source of data: idown.shp and veg.shp statewide gis coverage. Intersection of data was completed in Arcview 2.0 to create table. See http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/for gis shape files and metadata information. Bolded numbers are greater than 10%.

Table 2. Percent Cover Type by Land Owner/Type

Cover Type Group	B.L.M.	Bureau of Indian Affairs	Department of Energy	Forest Service	Military Reservations	National Parks & Monuments	Open water	Private	State of Idaho	U.S. Fish & Wildlife Service	All Lands
Agricultural crop and pastureland	3.2%	**20.7%**	1.1%	0.2%	1.5%	0.3%	7.0%	**50.2%**	3.6%	**15.3%**	16.6%
Alpine	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0%
Annual grasslands	8.9%	0.0%	0.7%	0.0%	**30.3%**	0.0%	0.5%	2.8%	3.8%	1.9%	3%
Foothills and Plains Woodlands	3.7%	0.0%	1.8%	0.6%	0.0%	**17.6%**	0.4%	0.7%	2.2%	1.3%	1%
Montane Forests	2.2%	5.7%	0.0%	**49.9%**	**11.1%**	1.2%	2.4%	**16.7%**	**29.7%**	0.4%	26%
Montane Forest-Steppe Transitions	4.0%	7.9%	0.0%	**15.4%**	2.8%	0.0%	0.7%	5.1%	9.3%	0.5%	9%
Montane Shrub fields	2.0%	0.2%	0.0%	4.7%	0.0%	0.0%	1.2%	2.1%	4.6%	0.0%	3%
Perennial bunchgrass seedings	7.8%	0.0%	1.3%	0.0%	**39.4%**	3.9%	0.1%	0.8%	2.3%	9.5%	2%
Recent timber harvest areas	0.0%	0.0%	0.0%	1.5%	0.6%	0.0%	0.0%	0.9%	2.1%	0.0%	1%
Riparian and Wetland Types	0.1%	3.0%	0.0%	0.2%	0.0%	1.0%	**80.6%**	1.1%	0.5%	**64.2%**	1%
Shrub Steppe and Grasslands	**67.7%**	**62.5%**	**95.1%**	4.2%	**12.2%**	**39.1%**	4.8%	**18.0%**	**38.2%**	6.9%	26%
Sub alpine Forests	0.2%	0.0%	0.0%	**13.3%**	0.0%	**36.9%**	0.6%	0.4%	0.7%	0.0%	5%
Sub alpine Parklands	0.1%	0.0%	0.0%	8.8%	0.0%	0.0%	0.8%	0.1%	2.8%	0.0%	4%
Urban and Industrial	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.6%	1.0%	0.0%	0.0%	0%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source of data: idown.shp and veg.shp statewide gis coverage. Intersection of data was completed in Arcview 2.0 to create table. See http://www.idwr.state.id.us/ftp/gisdata/shapefiles/statewid/ for gis shape files and metadata information. Bolded numbers are greater than 10%.

13.2 APPENDIX 2 - CARBON SEQUESTRATION OPPORTUNITIES IN IDAHO FORESTS

Carbon Sequestration Opportunities in Idaho Forests

By:

Brian Kummet, Nez Perce Tribal Forestry
Ladd Livingston, Idaho Department of Lands
Charley McKetta, Forest Econ Inc.

Idaho Carbon Sequestration Advisory Committee
Forestry Subcommittee
Draft Interim Report 12/19/2002

Carbon Sequestration Opportunities in Idaho Forests
Forestry Subcommittee

Draft Interim Report 12/19/2002

Brian Kummet, Nez Perce Tribal Forestry
Ladd Livingston, Idaho Department of Lands
Charley McKetta, Forest Econ Inc.

EXECUTIVE SUMMARY

Idaho forests already probably sequester more carbon than any other sector, and have potential to continually augment that sequestration. These forests are controlled by owners with very different objectives that cause some of their forests to act as net sinks and others as net sources of atmospheric carbon. The largest ownerships are controlled by the federal government whose current policies appear to conflict with active carbon conservation. However, the state has no regulatory power and minimal political influence over federal forests.

This report focuses on Idaho's state, tribal and private forests. They control less forest area (about 21%), but their active timber management may already be complementary with carbon conservation. Their potential to enhance sequestration by changing silvicultural practices is very large relative to other rural land uses.

Afforestation alone could sequester over an additional 120 million metric tons of CO_2. Other practices could substantially add to this total. We perceive that profit-oriented forest owners would respond positively to incentives and facilitation of carbon credit sales, but that regulatory intervention could be counter-productive.

The forestry subcommittee recommends that the state of Idaho continue to explore the opportunities afforded by developing carbon credit markets and adopt a facilitation posture toward the state, tribal and private production and sale of carbon credits.

A CONTEXT OF WOOD AND CARBON

Wood use for fuel, fiber and shelter framed the development of mankind. Wood use is described in its earliest literature. Perlin (1991) tracks western references to 2100 BC and concludes; "Wood, indeed, was our ancestor's chief resource."

Wood is a biologically fixed hydrocarbon and molecular carbon (C_2) is the dominant component of its substance. As society begins to overtly manage carbon, managing wood and forests that fix it is a necessary corollary. Our subcommittee focused narrowly on carbon within forest resource management. Readers should recognize that total carbon management goes more to changing the overriding relationship of humans to the wider set of fuels and materials that sustain our species. They should not miss the bigger role of wood by looking with us too closely at trees.

> "Wood is the most renewable and sustainable of the major building materials. Comparing the environmental effects of common building materials, wood has the least impact on total energy use, green house gases, air and water pollution, and solid waste. For every billion board feet of wood we use instead of other building materials like steel and concrete, we save 720 million tons of carbon dioxide emissions from entering our atmosphere."
>
> From "Forests, A Legacy to Our Children" 2002

FORESTRY SUBCOMMITTEE CHARGE

The forestry subcommittee sees its purpose as collecting background information about C_2 sequestration in Idaho forest management. Knowledge about forests' C_2 content and sequestration response to management, is an essential basis to the formulation of any policy that might influence foresters and forest owners to consider C_2 flux as a part of their forest land management objectives.

We believe that a summary of the forest carbon baseline data and a quantification of the C_2 aspects of management practices is a necessary starting point for policy recommendations. However, a manager's recognition of C_2 conservation as a relevant forest criterion and their adoption of any C_2 sensitive practices is an economic consideration. Economic choices must be made within the cost-benefit framework of other forestry objectives.

A FOCUS ON STATE, TRIBAL AND PRIVATE FORESTS

The State of Idaho has significant interests in the management by the National Forest System and the Bureau of Land Management. However, these agencies are controlled by congressional mandates, including the 1976 national forest management act, the 1969 national environmental policy act, and numerous later environmental acts including the 1973 Endangered Species Act. The precedence of federal legislation precludes any state control over federal forest carbon management. However, as interests of states, particularly in concert, may exert needed influences, we included some data on federal forests.

For state lands and private lands, the state has economic and regulatory interests in their functioning. We believe that this report should focus on the potential and socially appropriate exercise of those interests. Tribal forests are usually found on sovereign reservations, however, the state still has an interest in coordinating with those ownerships in the establishment of a mutually beneficial and cohesive carbon policy.

SNAPSHOT OF IDAHO FORESTS

On an ecological scale, forest lands across the country have been divided into land divisions or ecoregions, based on similarity of conditions. Idaho has 5 principle ecological provinces. Each of these has significantly different carbon budgets and potentials for enhancing carbon sequestration.

Bailey (1995) delimits ecoregions based on physiography, soils, potential vegetation and climate, classified in descending orders of scale, by domains, divisions, provinces, and sections. In Idaho there are five provincial-level ecoregions and each has significantly different carbon budgets and potentials for enhancing carbon sequestration.

Northern Rocky Mountain-Steppe Province:

The Northern Rockies are characterized by rugged mountains, separated by flat valley bottoms. Relief ranges from 3,000 to over 9,000 feet. Soils are less rocky than surrounding mountain provinces and have a volcanic influence providing for excellent soils that influence forest biomass. Precipitation is generally greater than the rest of the Rocky Mountains, averaging between 16-100 inches annually. Vegetation is unique due to precipitation and soil patterns resembling the Pacific Northwest. Common forest types are Douglas-fir, grand fir, and cedar-hemlock. The understory is characterized by a cover of ferns, forbs, and regenerating trees.

Palouse Dry Steppe Province:

This includes the Idaho portion of the Palouse region that extends into Eastern Washington. It has rolling hills and tablelands of moderate relief, ranging from below 1,000 to about 4,000 feet. Soils are loess-covered basalt. The area is in the rain shadow of the Cascade Range with average annual precipitation about 15 inches, most of which comes as winter rain or snow with sporadic spring and summer thunderstorms. Vegetation is primarily of grasses, forbs and small shrubs. Forested portions are small and mostly confined to moisture-holding aspects and draws. Forested areas include scattered stands of ponderosa pine and Douglas-fir with cottonwoods along riparian zones. Much of the Palouse has been converted to agricultural or urban uses.

Middle Rocky Mountain Steppe Province:

This central Idaho area is the Salmon River Mountains. Mostly granitic intrusions collectively make up the Idaho Batholith. Altitudes range from 3,000 to 9,000 ft. with the highest peak in the state at 12,000 ft. The batholith is deeply dissected; the granite is heavily weathered over large areas. Eastward is a basin-and-range area consisting of mountains, alluvial fans at their bases and floodplains along the streams. Ponderosa occupies lower elevations and drier aspects. Douglas-fir, grand fir, lodgepole pine and Engleman spruce are on the middle slopes. Subalpine firs are found on higher slopes.

Southern Rocky Mountain Province:

The Southern Rocky Mountain Province is confined to southeastern Idaho and the Yellowstone Plateau. The mountains are glaciated with elevations ranging from under 4,000 to 10,000 feet. Valleys are mostly developed farmlands or sagebrush steppe. Soils vary wildly from valley floors to high elevation sites. Climate is variable with warm, dry valleys where precipitation averages 15-25 inches. Mountain ranges are much cooler and precipitation is 40 inches or more. Much comes as snow. Because of great variation in elevation and aspect, soil types, direction of prevailing winds, rainfall and evaporation rates, mountain vegetation is a large-scale mosaic of conifers, hardwoods, and shrub/grasslands. The uppermost (alpine) zone is characterized by alpine tundra and absence of trees. Directly below, the subalpine zone is dominated by subalpine fir with Engelmann spruce with Douglas-fir at lower elevations. Lodgepole pine and aspen become dominant after fires. Grasses and sagebrush dominate at lower elevations with shrubs and mountain-mahogany.

Intermountain Semi-desert Province:

This province covers most of the southern third of the state, including the Snake River Plateau--extensive lava fields which have been folded or faulted into ridges. Numerous small mountain ranges average 7,000 to 9,000 feet. Lower valleys are between 2,000 and 4,000 feet. Soils are characterized by extensive alluvial deposits in stream floodplains streams and in fans at the foot of mountains. Annual precipitation is about 15 inches evenly distributed through the seasons, except for summer when little rain falls. Vegetation is primarily sagebrush, rabbitbrush, and bunch grasses. Riparian zones are lined with cottonwoods, willows and sedges. Forested areas are sparse in isolated mountain ranges of Douglas-fir, aspen and juniper. In the Owyhee Desert, there are large forests of western juniper, with occasional Douglas-fir.

For each province, forest inventory data can be converted to existing carbon content estimates. However, the potential for increased sequestration varies greatly by province. We must first establish a baseline to ask any meaningful questions about forest carbon flux in Idaho. That baseline should include both a static component, i.e. how much carbon is present, and a dynamic component, i.e. how the current pattern of forest dynamics (growth, removals, mortality) is affecting the carbon balance in the forestry sector. We need to be able to ask whether current forest management on different ownerships makes forests function as C_2 sinks or C_2 sources. Only then can we address how deliberate changes in forest stand management and forest fires management would change the current Idaho forest carbon balance.

IDAHO FOREST LAND AREA AND OWNERSHIP

Idaho forest acreage is owned and managed by a diversity of interests. Each has different objectives that might affect carbon flux and the potential for carbon sequestration. Of the 22.3 million total forest acres, 21.4 million are classified as timberlands, with the remaining 0.9 million classified as woodlands where juniper is the predominant species (Brown and Chojnacky 1996). Ownership acreages in table 1 are dominated by the federal government.

Table 1: Idaho Forest Land Acreage

OWNER	ACRES (MM)	% of TOTAL
National Forests	12.8	57.4
Reserves (Mainly Fed)	3.8	17.0
Forest Industry	1.2	5.4
Other Public	1.5	6.7
NIPF	2.0	9.0
Woodlands	0.9	4.0
Misc.	0.1	0.5
TOTAL	22.3	100

National Forests are lands owned by the federal government and managed by the USDA forest Service. The current management philosophy for National Forest Lands is "Ecosystem restoration" with limited opportunity for removal of products. (% change in sales/harvest cuts)

Reserved Forest lands are withdrawn from tree utilization. They include wilderness areas, study areas, national and state parks.

Forest Industry lands are owned by a company or individual and managed primarily for wood products.

Other Public lands include both federal and state ownerships such as the Bureau of Land Management, the Idaho Department of Lands, State and Federal Parks, State Fish and Game, county and other local government agencies.

NIPF: These are lands owned by non-industrial private owners generally with no more than 1000 acres. Management often includes objectives other than timber production.

Woodlands are lands where the plant community is typically composed of small, short-boled trees, with open canopy and intervening area occupied by grasses. They have less than 10 percent stocking of timber species.

IDAHO FORESTS' EXISTING SEQUESTERED CARBON

The literature on forest carbon is growing rapidly. The scientific determination of the variables and methods used to determine the total tons of existing carbon is an on-going study. Refining them lies outside our scope of work. We reference known documents and reproduce numbers where appropriate. Rather than provide an exhaustive survey of all relevant literature, we identified references that speak to specific questions relevant to our charge. The most applicable references are of two types: basic quantification of the forest carbon flux, and how the forest carbon balance can be affected by forest managers modifying the behavior of forests.

Forest Carbon Components

Forest carbon can be broken down into 5 basic components: soil by location: tree bole or stem, crown, site (soil, duff, and litter) and understory vegetation. Each component contains carbon; how much depends on the individual site and many variables such as species, slope, aspect, habitat type, region or area, etc. Some researchers lump various portions of the above components together (e.g. soil, duff, and roots comprise the soil carbon), so it is important to know what is included for calculations.

Generally, 30% of the carbon on a given site is located in the stem or bole of the trees. About 10% is in the crown (limbs and leaves). The leaf component cycles rapidly and their carbon flux is almost constant (Marshall 2002). 10% is in the understory if present, and approximately 50 – 60% is in the soil, duff and litter (Harmon 1998). Soil carbon is directly related to organic matter content. Even though organic material may often be only 2% of soil bulk density, soil is heavy, making the carbon content significant (Marshall 2002).

We use coefficients from the literature to quantify Idaho forest's current carbon content. This approach is a gross quantification for a ballpark idea of the forest carbon system magnitude. Stem carbon is almost a constant proportion of wood volume. It can be estimated from knowing wood volume and specific gravity for individual tree species.

Knowing the distribution of carbon within the system, allows a quick method of calculating the remaining on-site carbon by applying an expansion multiplier to measured stem biomass. This biomass multiplier then gives a gross estimate of carbon for the other forest components.

Idaho Gross Forest Carbon Baseline

Estimating Carbon on Timberlands: An Idaho Case Study, (Heath and Joyce, 1997) used numbers compiled by Birdsey (1992) from inventory data. They estimated that 1.47 billion metric tons of carbon are stored in Idaho forests. Approximately 41 percent of the stored carbon is in trees, 43 percent is in soil, 15 percent is in the forest floor and approximately 1 percent is understory vegetation.

The Heath and Joyce computations provide an excellent starting point for determining the absolute and relative scales of forest carbon sequestration. Table 2 compares Idaho forest carbon to other averaged western states.

Table 2: Average Forest Carbon Storage in the Western U.S.
1000 Pounds of C_2/acre by forest component (Birdsey 1992)

	--------- 1000 pounds of carbon stored per acre in ----------				
State	**Total**	**Trees**	**Soil**	**Duff/Litter**	**Understory**
9 Mountain States Average	124.5	47.1	61.3	15.0	1.1
3 Pacific States Average	167.6	67.7	76.7	19.7	3.4
22 Western States Averages	136.3	52.7	65.5	16.3	1.7
Idaho	**148.2**	**61.0**	**64.4**	**21.7**	**1.1**

To validate their computation, we multiplied the total Idaho forestland acreage (21,937,000 acres) by the per acre figure indicated in the table above (148.2 M pounds) and divide by 2.204 to convert to metric tons. We arrive at a figure very close to 1.47 billion metric tons of carbon.

Table 3 shows the estimated standing live woody biomass volume in Idaho forests by species (USDA-Forest Service FIA 2002). We converted above ground biomass data by species into gross estimates of live sequestered carbon. We multiplied each species unique specific gravity by a biomass factor of 2.25 and a carbon factor of 0.512 from another source to estimate fixed carbon weight by species.

Table 3: Calculating Existing Idaho Forest Carbon
Calculations by species

Tree Species	1000 Cu. Ft.	1000 Metric tons
Douglas fir	12,406,798	191,350
Ponderosa pine	2,734,030	37,085
Western white pine	436,775	5,127
Lodgepole pine	5,529,102	76,261
Whitebark pine	230,521	3,608

Limber pine	54,276	849
Western larch	1,476,368	24,455
Grand fir	5,749,109	80,608
Subalpine fir	3,727,191	43,751
Engelman spruce	2,487,765	30,825
Western hemlock	1,079,128	15,130
Mountain hemlock	573,679	6,734
Western redcedar	2,273,377	26,686
Total softwoods	**38,758,119**	**542,470**
Aspen	509,736	7,047
Cottonwood	292,513	4,044
Total hardwoods	**802,249**	**11,091**
All Species	**39,560,368**	**553,561**

Spreading total carbon weight over gross forest acreage implies that Idaho forests have on average 24.8 metric tones of per acre in tree stems. This estimate does not include root carbon or soil carbon which might expand estimates by as much as 40%. This is a much smaller estimate than implied by table 2 (61 metric tones/acre). Such low comparability suggests the variability of current gross carbon estimation methods. Sorting by tree species provides insights into natural sources of carbon variability due to a tremendous variability in forest stands. With further analysis, more accirate standing carbon estimates could be made by land site productivity, stand density and age classes.

IDAHO FORESTS C_2 FLUX COMPUTATIONS

Flux is the flow of forest carbon in continuous dynamic change. There is natural flux in the life of trees and in ecological cycles of succession. If managers are to influence flux and augment sequestration, they need to have a baseline measure of natural flux and knowledge of the manipulatable factors that influence it.

Forest Ownership Affects Carbon Flux

Forest ownership appears to have a large influence on background carbon sequestration as well as flux. Ownerships vary considerably by the types of forests they own and the objectives of ownership. For example, Inventory accumulation is the result of managerial policies affecting forest structure and removals, the biology of growth on the age classes and species represented and how the forest health affects the rate of mortality. Different owners would manipulate each of these factors differently.

Table 4 shows how existing wood volume inventory is distributed. Using the same conservative stem biomass factor used in building table 3, we assume that standing forest biomass is directly proportional to fixed carbon. This would actually vary by species and forest conditions that also vary by ownership. Our approximations are crude, but it is clear that Idaho's fixed forest carbon inventory is overwhelmingly controlled by the national forests (76.7%). The forests targeted by this report have relatively small standing carbon inventories, private/tribal forests (14.6%), and state forests (5.7%).

Table 4: Forest Inventory Wood and Carbon by Ownership
Source: USDA-Forest Service FIA data (2002)

Forest Ownership	Wood Volume MMCF	Carbon Wt MM MT	Distribution %
National Forests	30,641.4	428.7	76.66%
BLM/other public	1,110.2	15.5	2.78%
State of Idaho	2,279.4	31.9	5.70%
Private/tribal	5,940.3	83.1	14.86%
Total	**39,971.3**	**559.3**	**100.00%**

Current Background Forest Carbon Flux Rates

Changes in forest carbon (flux) are associated with forest area changes, stand treatments, wildfire, growth, removals (harvests), and non-fire mortality. Most of these changes are (or can be) influenced by ownership management policies. Forest area changes are ignored as land uses are relatively stable. We have not yet found estimates of Idaho wildfire carbon releases. Stand treatments are intentional changes in forest character that are covered in a later section.

We focus on growth, removals, and non-fire mortality as regular background processes for the baseline estimate. Table 5 shows the fixed carbon implications of only forest stem volume change rates as of 2000. For these stem carbon calculations, we hold soil, branch, and root biomass constant. Growth and mortality rates in cubic feet/year were derived from Resource Planning Act statistics. Harvest statistics in MBF/year are from USDA-Forest Service Region 1 reports. We standardized volume estimates and converted to fixed carbon weights.

Table 5: Forest Carbon Flux by Ownership
Million metric tones (MM MT) per year

Forest Ownership	Growth	Mortality	Harvest	(G+H)-M
National Forests	5.2	5.1	0.4	0.5
BLM/other public	0.3	0.1	0.0	0.2
State of Idaho	0.7	0.2	0.6	1.1
Private/tribal	2.6	0.6	2.0	4.0
Totals	**8.9**	**6.0**	**3.0**	**5.9**

Idaho's forest carbon inventories are experiencing significant background growth (+1.6%/year). Inventory accumulation is offset by mortality (- 1.1%/year) and harvests (-0.5%/year). Normally, managed forests attempt to capture mortality in well-timed harvests, but Idaho has almost twice as much mortality as harvest.

The calculated (G+H)-M is a rough estimate of net carbon accumulation at current rates. Growth stores carbon in tree boles; harvest stores carbon in products; and mortality releases carbon as dead trees decay. Our use of total harvest as a storage indicator overstates that form of sequestration as some harvest volume is waste, and some wood product also decays, releasing carbon. Still, Idaho forests appear to be increasing carbon sequestration as an ordinary part of timber management.

Table 5 also demonstrates that carbon flux varies wildly by ownership. Most of the forest carbon sink function is on actively managed private and tribal forests even though they control a much smaller portion of Idaho forests. The fact that state, tribal and private forests have relatively less accumulated inventory and more carbon sink function is counterintuitive. More intensive timber management attempts to capture the most possible site productivity as rapidly harvestable product. Growth (carbon fixation) is optimized, rotation cycles are short, mortality is avoided or captured, and the forest carbon is repeatedly stored in wood products rather than as standing inventory.

The national forests had most of the forest area (57%) but these lands hold even more of the volume (77%). There is relatively little annual harvest on these older, denser stands. As a result growth is low. Mortality is high and has been increasing rapidly over the last three decades (O'Laughlin et al 1993). Although they have enormous volumes of stored carbon, this ownership probably functions as a net carbon source from the estimated mortality, decay and the uncalculated large fires.

INFLUENCING FOREST CARBON SEQUESTRATION

Forest carbon flux is extremely malleable. Historical carbon stores that have been established as an artifact of prior carbon insensitive management can be augmented or liquidated. From a given carbon stock, future flux can be similarly redirected. As carbon sequestration appears to be correlated with overall intensive timber management, increased timber and carbon management may have financial as well as environmental complementarity.

Silvicultural practices are management activities that change the nature of the forest stand or ecosystems. These practices are already exercised to varying extents for a variety of reasons. They may enhance wood product value and profits, change watershed quality, and provide wildlife habitat. Many traditional practices already have a direct effect on the degree of carbon sequestration. These individual practice effects may be positive or negative. This section identifies common practices in Idaho forest management and reviews their current flux effect. We note trade-offs with carbon sequestration objectives and make rudimentary quantifications of their potential influence.

Defining Units of Forest Carbon Production

To influence management, first the carbon product must be quantified. The term carbon credit has had many different meanings and has been known by many different terms. Now that carbon sequestration is becoming an accepted objective, one general definition is emerging. Most agree that a "carbon credit" is used to represent an amount of organic carbon sequestered in wood or soil. It is equivalent to the removal of one metric ton (2,204.6 pounds) of carbon dioxide (CO2) from the atmosphere. Most people define a carbon credit as one metric ton of CO_2 equivalents instead of a ton of C_2 alone.

The transfer of solid carbon compounds into gaseous CO_2 means that for each unit of carbon converted into gas, 3.67 units of CO_2 are produced (NCOC 2002). This conversion uses the molecular weight of carbon (C=12) and oxygen (O=16). Therefore, when one unit of carbon combines with 2 units of oxygen (12 + 16 + 16 = 44/12 = 3.67), the result is 3.67 units of CO_2 for each unit of C_2.

Standards for Calculating Carbon Yields

As there are currently no uniform standard guidelines for carbon sequestration projects, there is not one standard method of calculating carbon yields from forests. However, most carbon authorities agree on the following basic steps that have emerged as the basis in calculating carbon yields or credits:

1. Establish baseline conditions – How much carbon is there now?
2. Establish a project case scenario – How much carbon will be there at the completion of a project?
3. Calculate net carbon changes – How much additional carbon did your project actually produce?

4. Address special considerations of carbon sequestration projects:
   - **Additionality** – A project must reduce carbon emissions or increase a carbon sink as a direct result of an intentional activity that would not have occurred otherwise.
   - **Leakage** – Will the emission reductions in this project cause emissions elsewhere that partially or totally offset the emission reductions of the project?
   - **Permanence** – How long will the project build and maintain a carbon pool? Is it likely that the project will continue to sequester carbon after the initial contract has expired?
   - **Risk** – What are the potential risks that the project will not be implemented or will be lost to other factors such as disaster, abandonment, politics, etc.
   - **Duration** – How long is the commitment period of the project? When does the contract expire?
   - **Transparency and Accuracy** – How clear and accurate is the plan, so as to provide a clean audit trail for subsequent verification?
   - **Monitoring and Verification** – How will the project be monitored to sample carbon pools as they are sequestered and compare this to the original plan or contract?

Silviculture and Carbon Management

Silvicultural practices are management activities that change the nature of a forest stand or forest ecosystems. Foresters employ these practices for a variety of reasons. They may enhance wood product value, change watershed quality, or provide wildlife habitat. Many traditional practices already have a direct effect on carbon sequestration. These effects may be positive or negative. This section identifies common practices in Idaho forest management and reviews their current flux effect. We note trade-offs with carbon sequestration objectives and make a rudimentary quantification of their potential influence. Typical contemporary silvicultural practices include the following.

- **Stand Composition Control**
  This is regulating a stand's species composition to the species or mix of species most suited to a location either biologically, or economically. It is accomplished with species cutting targets and regulating species regenerated, either in natural seeding or by planting. Tree species differ in carbon sequestration ability; by growth rate and density. Those with more dense wood contain more carbon per unit volume. Examples are Douglas-fir with a specific gravity of 0.473, ponderosa pine with 0.416, spruce/fir with 0.349 and western larch at the highest with 0.508 (Birdsey, in Sampson et al. 1992). Changing the species mix can affect the amount of carbon sequestered, either positively or negatively.
- **Stand Density Control**
  Thinning regulates the number of trees and their size class distribution in a forest stand. Tree/stand density can significantly impact forest carbon. Vigorously growing trees sequester carbon more rapidly than poorly growing ones. They are generally more healthy and resistant to attack by insects and diseases and will remain alive, sequestering carbon for longer periods. Conversely, trees in dense stands grow slower and are subject to attack by insects and diseases, thus reducing the carbon sequestration ability and longevity. Sparsely occupied stands will be less productive economically and in carbon fixation. Example methods include:

  Commercial thinning_— cutting salable trees to control forest density. This causes a short-term release of carbon in slash burning and the decay of tops, branches and folliage, however, log sales provide long-term sequestration through the utilization of forest products.

  Precommercial thinning_— cutting solely to improve the stand growth, health or structure. Cut trees are generally too small to sell, thus there will be a short term carbon releases as cut trees decay. This will be offset by the increased growth of the trees left on the site. As merchantable log sizes are becoming smaller, more thinning is becoming commercial

Interplanting – establishing young trees among existing forest growth by natural seeding or by planting. When there are fewer trees or plants than can be supported by the physiography of the site, interplanting provides obvious new carbon sequestration.

- **Protection and Salvage**
  Severe tree mortality is caused by insects, pathogens, fire and wind. Dead trees eventually release of carbon through decomposition or directly by burning. Accumulations of dead fuels increase the risks of fire to nearby living trees. Losses of all types are greater in unmanaged stands where tree high density contributes to competition, low tree vigor, growth loss, and increased impact of the previously mentioned factors. Substantial gains in carbon sequestration are possible through increased forest health and prevention of losses. This can be achieved through management that optimizes (usually reduce) stand density and removes suppressed, poorly growing trees. Salvage of dead and dying trees contributes to productivity and sequestration of carbon by increasing site occupancy and the utilization of wood products. Direct control of damaging agents such as bark beetles, dwarf mistletoe, or fire prevents tree killing providing a significant increase in fiber production and carbon sequestration. More detail on the role of forest insects and diseases and efforts to prevent or control damage resulting from them is presented in Appendix B.
- **Controlling Rotation Length**
  Rotation length, how old trees are before harvest, is the most common and influential silvicultural decision. Rates of stand carbon sequestration are influenced by tree size, age and vigor. Younger trees grow faster and are more efficient at sequestering carbon. Growth slows with age and older trees are more subject to decay, attack by insects, and diseases with a net carbon loss. Optimal rotation age varies. Maximizing mean annual increment leads to long rotations and large stand carbon accumulations, but very slow product storage. Highest financial returns leads to lower average growth rates and less stand accumulation, but more rapid cycling to products. An optimal carbon flux rotation is probably between these cycles and could be uniquely determined for each site. Then joint revenue and carbon flux could be optimized depending on landowner incentives for carbon fixation.
- **Regeneration Harvesting**
  When harvesting is a management objective, it is necessary to replace trees that have been removed. This is "regeneration," a task accomplished by artificial or natural reproduction. Planned silvicultural treatments to remove old trees while creating an environment favorable for establishing new trees are referred to as regeneration harvests. Sequestered carbon is moved from the forest to products. Slash left after the cutting is often burned with an immediate release of carbon into the atmosphere. Carbon sequestration in new trees starts as soon as the new crop of trees is established. Regeneration harvests have many variants:

  Even-aged -- creating a stand composed of a single age class or even-aged strata. Tree ages in the same area are usually within ±20 percent of the rotation age. Examples of even-aged regeneration harvests include:

  Clearcuts--entire stands are removed in one cutting with regeneration. Often used to stimulate reproduction of shade intolerant trees, clearcuts ecologically mimic catastrophic events such as wildfire. Regeneration is often artificial.

  Seed-tree cuts -- the majority of the mature trees are cut in one entry except for a small number of seed trees left singly or in small groups to provide seed for a new generation.

  Shelterwood cuts -- mature timber is removed in a series of successive entries over the rotation. This produces three or fewer layers of generations being essentially of the same age.

  Uneven-aged -- planned sequences of continual harvest entries designed to maintain and regenerate a stand with three or more intermingled age classes. The principal example is the **selection method** where harvests cut widely spaced individual trees or small groups of trees at relatively short intervals repeated indefinitely. Used particularly for shade tolerant species, reproduction is usually by natural seeding from the remaining stand. Stored carbon can be high in uneven-aged stands as there is a continuing stand of trees at all times. Carbon flux will depend on how intensively this harvest method is practiced. Sequestration is enhanced through the frequent extraction of forest products.

- **Pruning** – removes side branches and multiple leaders from standing trees, usually to improve timber quality, or to improve aesthetics or health. It can marginally reduce growth rates. As cut branches are left on the forest floor to rot, this practice contributes, albeit at a small scale, to the release of carbon.
- **Riparian zone conservation/restoration –** preserves or restores stream-side vegetation. This helps prevent erosion and siltation of the streams, and maintains habitat for fish and wildlife. Since the effort promotes growth of vegetation, it provides an opportunity for carbon sequestration.
- **Edaphic (site) modification –** enhancing seedling survival and rapid tree growth. Typically these treatments also increase carbon sequestration. These practices include fertilization, irrigation, and control of competing vegetation. Fertilization and control of competing vegetation are common forest practices used when the economic return is positive. Irrigation can only be used on a small scale usually in plantations. This is often done where fast-growing trees are planted for specific purposes such as to provide fiber for pulp mills.
- **Fire management –** as fires result in immediate release of carbon, their use in forest management may be looked upon as suspect in value relative to carbon sequestration. This is especially the case with wild fires that burn many acres, releasing tons of carbon as they burn. The general philosophy for dealing with **wildfires** is to let them burn if they are in wilderness areas and are not threatening other resources. Those fires burning in commercial forest or that do threaten other resources are suppress as quickly as possible. Burning also helps recycle all nutrients tied up in the wood to make it available to the next generation. However, fire used as a management tool needs to be looked at more closely.

  Broadcast burning—widespread low intensity fire to prepare sites for planting. It would be a major contributor to atmospheric carbon, yet many sites need this type of treatment to start new stands.

  Underburning --reduces competing vegetation allowing surviving trees to grow more vigorously. There is initial litter and duff carbon release, but long-run increases in carbon that is sequestered in the boles of the trees where it will remain until it is harvested or it dies of natural causes.
- **Regenerating Unstocked Areas**
  Logging, clearing of land for agriculture as well as fires and other catastrophic events have created many large, open areas that often can only be reforested by planting. Cutting practices may also result in temporary reductions of the number of trees growing on a site that are best remedied by planting. **Restocking** efforts will cause an immediate increase in carbon sequestration on these sites. **Afforestation** is the process of converting non-forest lands such as crop agriculture or pastures into forest stands. Such land use conversions of pasture land or lands with similar cover types often provide the greatest potential increases in carbon sequestration.

INFLUENCING IDAHO SILVICULTURAL DECISIONS

Getting Idaho forest owners to modify silviculture to increase sensitivity for carbon issues would vary significantly by type of owner. National forest and other federal forested agencies respond primarily to national political and regulatory influences. We address only the potential modification of forest management on state, tribal and private forests. Our ownerships all have significant financial objectives even though each group has different sets of non-financial management criteria as well. In most of them a change in operating or regulatory costs, or in revenues has very predictable effects on the choice of silvicultural activities. As we consider influencing forest carbon decisions, the mechanism will have predictable qualitative effects on growth rates, rotation ages, intensity of management (amount of silvicultural practices), propensity to hold inventory, and incentives to change land area allocated to forests.

Forest carbon policy intervention can appear to landowners as costs (typically from taxes or regulatory compliance) or benefits (such as tax breaks, carbon credit sales, or subsidies). For example, the value of a carbon credit has been hypothesized from $2 to $18. If forest owners could produce and sell enough of these, there might be substantive chances in their behavior.

If we condense the set of possible influences into: 1) an increase in management costs and 2) an increase in forest revenues, we can extrapolate from Hyde's (1980) predictive analytics of such changes. The behaviors are caused by complex interactions of financial indicators with the interest rate and biological growth, but the basic responses when these are held constant are summarized in table 6. We qualify a general carbon sequestration response (- or +) set from the practice descriptions above. Individual cases can differ from the general response.

Table 6: Forestry Responses to Higher Costs or Revenues

Effect	**+Δ Costs**	**Δ C_2 flux**	**+Δ Revenues**	**Δ C_2 flux**
Rotation Age	Longer	–	Shorter	+
Growth Rate	Lower	–	Lower	–
Practices	Fewer	–	More	+
Inventory	Lower	–	Lower	–
Forest Acres	Fewer	–	More	+
Forest Fires	More	–	Fewer	+

The growth rate response to increased costs is particularly counter-intuitive. There is a longer rotation due to decreased investment. Longer rotations usually have higher average growth rates for the same investment, but the investment effect is empirically larger than the rotation effect on growth. Also, less product is cycled less frequently. The qualitative indicators suggest that interventions increasing costs without reward should actually lower forest carbon flux. Incentives generally increase it although not all factors are affected the same direction.

CALCULATING CARBON POTENTIALS IN AFFORESTATION

Afforestation is the largest potential contributor to increases in carbon sequestration. Not only does creation of new forest inventory imply a large new carbon sink, increased forest products have long-term carbon storage properties. Land use conversion usually depends on the economic differences between agricultural or pastoral use and timber investment potential. Conversion of high productivity agricultural lands is unlikely, however, the land use allocation margin between low quality ag and forest is a function of relative crop yields, relative crop values, transportation costs and the interest rate (Barlowe 1978). Carbon sequestration incentives would accelerate the process.

While we can't predict how many acres would be converted without knowing financial variables, we do have data on the rate per acre of relative carbon fixation that could be generated. These conversions measure soil and biomass carbon, but calculate only net carbon gain between uses. Many variables and different combinations of these variables make it very difficult, if not impossible, to accurately predict a maximum level of carbon that could be sequestered in Idaho forests.

The intent of our report is to simply demonstrate how some of the generally accepted silvicultural practices in forestry could impact carbon storage and flux in Idaho forests. For example, planting trees into unforested areas is probably the highest response practice. Using published acreage figures for poorly stocked and non-stocked forest ground (Brown & Chojnacky, 1991) and acreage suitable for conversion to trees from pasture and marginal agricultural land (Sampson and Hair, 1996), we can estimate how much impact this one practice might have in Idaho's carbon storage.

Table 7: Idaho Lands Suitable for Tree Planting

Land Class	Acres
Poorly Stocked Forest Land	3,493,040
Non - Stocked Forest Land	1,097,831
Pasture land to Forest Land	273,100
Marginal Agric. Land to Forest Land	600,900
Total all land classes	**5,464,871**

We make broad assumptions such as: 1) realistically, afforestation might be financially feasible on only 20% of biologically suitable acreage; 2) poorly stocked forest land is understocked by 75%; 3) pasture land has no forest cover; and 4) agricultural land has no carbon in the top one foot due to repeated tillage. Using Birdsey's forest component figures from table 3 above, and expanding table 7, we find that afforestation could potentially fix about 34.734 Million Metric tons of additional carbon (table 8).

Table 8: Carbon Potential of Afforesting 20% of Suitable Idaho Lands

Land Class	20% of Acreage	Pounds of Carbon/acre	Carbon Metric Tons
Poorly Stocked Forest Land	698,608	55,413	17,564,397
Tree Component		45,721	14,492,233
Soil		6,442	2,041,844
Forest Floor		2,174	688,940
Understory		1,077	341,380
Non – Stocked Forest Land	219,566	70,653	7,038,591
Tree Component		60,961	6,073,038
Soil		6,442	641,733
Forest Floor		2,174	216,528
Understory		1,077	107,293
Pasture land to Forest Land	54,620	82,768	2,051,180
Tree Component		60,961	1,510,749
Soil		16,104	399,099
Forest Floor		5,434	134,660
Understory		269	6,673
Marginal Agric. Land to Forest Land	120,180	148,190	8,080,524
Tree Component		60,961	3,324,089
Soil		64,417	3,512,539
Forest Floor		21,735	1,185,169
Understory		1,077	58,727
TOTALS	**1,092,974**		**34,734,692**

This is metric tons of C_2, not CO_2. If we multiply our figure by 3.67 to convert to carbon credits, we sequester 127.5 million metric tons of CO_2. Even at only $2/carbon credit, we are looking at a reasonably significant forest by-product. Although the numbers of new carbon credits would probably never be as dramatic as our assumed afforestation alone, there are more carbon credits that could be calculated for all of the other silvicultural practices that are discussed in this document.

CARBON SEQUESTRATION EXAMPLE CASES

There is not a carbon registry for Idaho, so accurately quantifying active carbon projects is difficult. Thus far, interest in carbon sequestration projects peaked in year 2000 or 2001. Forest carbon projects are limited to a few small tribal and non-industrial early adopters. Although carbon information meetings were attended by state and federal agencies as well as private industry, members of this committee are not aware of any current projects being implemented or set up by these agencies or companies. The following examples are representative of Idaho forest carbon projects so far.

The Nez Perce Tribe

The Nez Perce Reservation is in North Central Idaho. They became interested in carbon sequestration in 1995 as a possible funding source to replant failed plantations. In August, 1997 tribal forestry began working with the Upper Columbia RC&D on potential Carbon Contracts. The tribe also became a working member of the Pacific N.W. Carbon Sequestration Coalition (6/99) and the Montana Carbon Offset Coalition (10/99). The latter became the National Carbon Offset Coalition (NCOC) in 2002.

The Nez Perce Tribe has developed five carbon sequestration projects or contracts. Four have been reforestation projects and one is an afforestation project. Afforestation has drawn the most interest, converting four hundred (400) acres of marginal agricultural ground into a forest. Together, a conservative sequestration estimate is 336 thousand metric tons of CO_2 on 1,033 acres. Another 1,000 + acre afforestation project is being developed. The tribe has not yet actually sold a carbon contract, but they are confident that it is just a matter of time.

Upper Columbia RC&D

Although the Upper Columbia RC&D is located in Spokane, Washington, forester Tim King is regarded as a carbon sequestration leader throughout the Pacific Northwest. He aided and facilitated other RC&D's in Idaho in developing carbon projects. They developed many individual small landowner projects in North Idaho. Two private forests totaling one hundred acres were part of a carbon sale to Pacific Corp. in 1993 & 1994. In 1995, 1996, and 1997 another eight private land owners (~ 1,000 acres) in North Idaho benefited from another sale, this time with the Tenaska Corporation. With both of these carbon sales many other private landowners in other states and two Native American tribes also benefited. However, because of internal financial and political reasons, the Upper Columbia RC&D is no longer facilitating carbon sequestration contracts. As a result, several of the latest private forest projects developed registered carbon credits that remain unsold.

National (Montana) Carbon Offset Coalition - NCOC

The National Carbon Offset Coalition (NCOC) is comprised of eight Montana non-profit organizations. NCOC provides an opportunity for landowners, public, and private corporations, tribal, local and state governments to participate in a market-based carbon conservation program to help offset greenhouse gases impacts. It is designed to assist planning carbon sequestration projects and documents potential carbon credits in a format that follows international standards and protocols, while meeting the needs of potential buyers. (NCOC 2002)

Although this NCOC is not located in Idaho, it has facilitated two projects with the Nez Perce Tribe in Idaho. They have also facilitated one carbon contract sale for the Confederated Tribes of the Salish and Kootenai in Northwest Montana. NCOC remains very active in seeking and promoting viable carbon projects nationwide. They work directly with Montana state government as well as various federal agencies such as the Department of Energy (DOE) and the Environmental Protection Agency (EPA) on carbon sequestration policy.

POTENTIAL ROLE OF STATE GOVERNMENT

The scientific study of organic carbon fixation is well-developed, but the application of that science to the practical management and manipulation of atmospheric carbon is relatively new. Many global warming experts have attributed warming to human releases of C_2 particularly the use of fossil fuels. The concern is widespread enough to cause international policy formation on the rate of fossil fuel C_2 emissions. The Kyoto protocol was an international treaty defining the acceptable emissions levels.

Intentional mitigation of atmospheric C_2 levels, while technically feasible, has been controversial and there is neither international treaty nor national governmental policy on its exercise. As the U.S. Congress has not ratified the Kyoto accord, there is no coherent American national mandate to reduce or use mitigation to reverse C_2 emissions. There are regulatory constraints calling for new industrial carbon emissions mitigation that have stimulated interest in carbon offset contracts. The fact that agricultural and forestry sectors may have very large potential in such mitigation has led to a few institutional experiments in fostering or encouraging mitigation practices.

The active sequestration process is new and takes many forms. Most of the active sequestration projects are experimental private transactions between C_2 emitters and carbon credit brokers. These brokers supply a unit definition to quantify the rate and total amount of fixed carbon. They organize and small coalitions of agricultural and forest owners to change their vegetative rate of carbon fixation producing these credits. These credits are accumulated into contract packages that are sold to carbon emitters who need to mitigate C_2 emissions. The arrangement is usually a private contract that specifies the agreed sequestration parameters. These include:

1. Defining carbon credits—1 metric ton equivalent of atmospheric CO_2
2. Methods of measuring the rate and total production of carbon credits
3. Specifications for distinguishing mitigation credits from existing C_2 inventory and fixation from existing management from new sequestration
4. Spatial identification of the sequestration project
5. Timespan of credit production and degree of long-run sequestration in vegetative inventory or final product
6. Agreement on the production and transaction value of credits
7. A system of reassigning rights to those credits
8. Acceptable patterns of compensation
9. Provisions for contract change
10. Assignment of credit loss risk
11. Provisions for monitoring credit production
12. A protocol for certifying the quantity and quality of credits, and
13. Provisions for adjusting contract specifications

Early carbon credits transactions have been competitive market negotiations with little participation of government other than specific national case requirements for mitigation such as in new power plant licensing. The role of state and local governments in carbon sequestration varies from market facilitation to regulation and no standard pattern has evolved.

Sequestration activities could potentially be organized in either centralized government or decentralized market processes. Government involvement in the production of a marketable commodity is usually justified by the failure of private markets to correctly provide public goods, usually from ignoring the non-financial social costs or social benefits of economic activities (such as carbon and global warming). Government intervention can take many forms;

1. **Moral suasion** includes public organization of information and social pressures to suggest socially preferable changes in private carbon emitter and sequestration behavior. For example, a public education program on the social costs of increased atmospheric carbon or an enlightenment on C_2 conservation practices in forests.
2. **Regulation** is the formal involuntary legal process of specifying allowable behavior for emission and sequestration. Emissions caps on new energy facilities or new car fuel requirements are existing emissions regulations. On the sequestration side, there could eventually be penalties for not maintaining a minimum vegetative cover crop on open lands.
3. **Taxes and subsidies** are involuntary negative and voluntary positive financial incentives to adjust carbon related production and consumption behavior. Government sets socially optimal targets and charges or pays individuals that choose to deviate from them.
4. **Direct production** is the nationalization or other form of centralizing ownership and decision authority in carbon sensitive sectors. The national forests could perform direct government sequestration. Public transit replacement of private automobiles could reduce emissions.

These are widely extreme categories of government involvement potential. The most appropriate carbon transaction system may be between the extremes of lassiz faire market non-interference and soviet style autocracy. The social goal is to achieve a new standard of environmental quality efficiently—the most gain for the lowest cost.

Osborne and Gaebler (1992) argue that neither organizational extreme is an efficient provider of goods with public overtones. Private markets malfunction and so do governments. In designing systems they suggest vesting each group with the responsibility to achieve the parts where they have the highest relative efficiency.

Government is good at providing information, setting standards and institutional settings, politically identifying public values, and enforcing contracts. The private sector is good at optimizing investment levels, efficiently allocating resources, effectively executing projects and production, and the transaction and distribution of goods. The actual carbon sequestration process could occur on both private and public forests. We presume that a joint government/private sector structure would make any Idaho carbon sequestration efforts more effective. To that end, we list the potentially **positive** functions of state government in regulating, organizing or managing a combined state/private carbon sequestration process.

Function 1: Provide carbon sequestration standards.

a. The state could codify the current working definition of a carbon credit.
b. It could standardize the production estimation process and provide technical expertise on converting Idaho sequestration practices into long-run estimates of fixed carbon.
c. It could provide carbon credit grading to identify credit quality and distinguish from existing carbon sinks.

Function 2: Facilitate carbon credit information

a. Establish a spatial data base to estimate locate the existing Idaho carbon sinks, their carbon content and state of flux.
b. Begin an extension effort to publicize carbon sequestration opportunities, describe the importance of conserving existing carbon and educating potential carbon sequesters
c. Prepare regular analyses of carbon sequestration polices, existing markets and sales potential to identify carbon credit current values and the potential timing for future investment
d. Identify and fund potential technical research projects on: forest soil and biomass carbon, carbon BMP’s, role of agricultural burning & forest fire in carbon flux and credit production

e. Identify and fund potential project investment research establishing cost effectiveness guides for possible sequestration BMP's

Function 3: Facilitate carbon credit transactions to lower their costs

a. Act as a clearing house for participating carbon sequestration to organize participants and advertise mitigation credit availability
b. Use the central data base to spatially locate potential carbon sequestration projects and maintain a spatial data base on the changing status of existing and potential credit production
c. Develop a suggested contract format for carbon credit transactions
d. Use the central data base and GIS mapping to assist landowners in defining the location and parameters of new projects

Function 4: Provide an institutional and regulatory setting

a. Establish a new office of carbon management in the Idaho Dept of Agriculture
b. Study existing ag and forest regulations to identify the need for new statutes and the revisions of existing regulations where their enforcement might conflict with carbon
c. Explore the creation of carbon credit insurance similar to crop insurance to reduce sequestration production and contract risks
d. Study the effect of existing agricultural and forest tax systems with respect to their effects on existing carbon sink conservation. Evaluate tax incentive mechanisms for proactive sequestration.

Function 5: Enforce carbon credit contracts and standards

a. Develop a centralized program of carbon project inspection and production certification
b. Set non-compliance sanctions and penalties relevant to breech of carbon credit contract, non-compliance or fraud

Function 6: Manage public lands carbon sequestration activities

a. Establish carbon credit sales as a legitimate product of state land management
b. Recommend how current state land practices could be adapted to increase salable carbon credits
c. Coordinate state & private activities with federal lands agencies to optimize the Idaho potential for credit sales

RECOMMENDATIONS OF THE FORESTRY SUBCOMMITTEE

The forest subcommittee generally supports the interest of the Idaho legislative and executive branches in facilitating the development of carbon sequestration opportunities for Idaho's state, tribal and private forests. However, we expect that some regulatory approaches could actually increase costs to carbon sequesters and actually reduce Idaho's capacity to capitalize on this new, and environmentally beneficial, forest product. From the list of possible roles above, our specific recommendations for immediate consideration include:

1. Expand this committee's exploratory research into a more detailed evaluation of what other states have accomplished and use their mistakes and successes as a guideline to develop Idaho forest carbon policy.
2. Charge a state agency (such as Idaho Dept of Agriculture) to provide standards & guidelines for defining, measuring, estimating and monitoring carbon production that are compatible with national and international systems.
3. Fund the calibration of an existing baseline model to quantify the baseline levels of forest carbon sequestration.
4. Contract research to actually measure the carbon response of Idaho forest types to various silvicultural practices and create carbon projection protocols that could easily be followed by foresters.

5. The state should provide or fund adequate extension training to Idaho foresters and forest owners to enhance awareness on carbon sequestration opportunities, methods, and marketing potential (i.e. how to sequester carbon).
6. The state should maintain an updated and easily accessible list of carbon credit opportunities (perhaps a web site) and provide marketing information and assistance to citizens interested in selling carbon credits.
7. Develop guidelines and training for setting up carbon projects and calculating the carbon credits on specific sites. These should be very similar to other states and countries, realizing that items may change as the carbon sequestration programs and the science surrounding them evolve.
8. The state should provide a legal standard contract format and process for carbon credit sales.
9. Pass the necessary enabling legislation to authorize the Idaho Department of Lands to design carbon projects and implement carbon credit sales to enhance the state educational endowment fund when credits become a viable and tradable commodity.
10. Provide one (1) entity or agency to register all carbon projects and credits within the state and group these projects by type (e.g. reforestation, afforestation, no-till agriculture, etc.). Project registry should be sensitive to special consideration projects such as: tribal jurisdictional issues, industry with ownership in more than one state etc.

We believe that this is just a starting point for facilitating this new market. The process should be reevaluated at regular intervals and adjusted to meet new considerations as they develop. However, we expect that our recommended approach establishes a design philosophy for the state and private cooperation to develop Idaho's forests to their highest sustainable financial and environmental potential.

LITERATURE CITATIONS

Bailey, R.G. 1995. Descriptions of the Ecoregions of the United States. 2nd Ed. Misc. Publication 1391 (rev.) Washington DC:USDA Forest Service

Brown and Chojnacky. 1996. Idaho's Forests, 1991. Resour. Bull.. INT-rb-88. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 63 p.

Colorado State Forest Service, the South Dakota Resource Conservation and Forestry, the Wyoming State Forestry Division, the Intermountain Forest Association, the Society of American Foresters, and the USDA Forest Service. 2002. "Forests, A Legacy to Our Children" jointly produced pamphlet.

Heath, Linda S. and Joyce, Linda A. 1997. Carbon Sequestration in Forests as a National Policy Issue. Estimating Carbon on Timberlands: Idaho Case Study. Proceedings of the National Silviculture Workshop, May 19-21, 1997, Warren, PA. USDA Forest Service Northern Forest Experiment Station, General Technical Report NE-238.

Hyde, William F. 1980. *Timber Supply, Land Allocation, and Economic Efficiency*. Resources for the Future. Johns Hopkins University Press: Baltimore. 224 pp.

Marshall, John. 2002. Personal communication. Academic forest physiologist. University of Idaho 10/14/2002.

O'Laughlin, J, J.D. MacCracken, D.L. Adams, S.C. Bunting, K.A. Blatner, and C.E. Keegan. 1993. Forest Health Conditions in Idaho. Report # 11. Idaho Forest, Wildlife, and Range Policy Analysis Group. University of Idaho. Moscow.

Osborne, David, and Ted Gaebler. 1992. *Reinventing Government*. Addison-Wesley: Reading Mass. 504 pp.

Parks, Peter J., Brame, Susan R., Mitchell, James E., Opportunities to Increase Forest Area and Timber Growth on Marginal Crop and Pasture Land.

Perlin John. 1991. *A Forest Journey: the Role of Wood in the Development of Civilization*. Harvard University Press: Cambridge, Mass.

Sampson, R. Neil and Hair, Dwight. 1996. Forests and Global Change: Volumes I & II Forest Management Opportunities for Mitigating Carbon Emissions. American Forests, Washington D.C.

Sampson, Neil. 2002. Project Planning Handbook: Forestry Projects to Create Carbon Sequestration Units (CSU's) Version 1.0 – 2002, National Carbon Offset Coalition

Smith, David M., 1962. *The Practice of Silviculture*, seventh ed. John Wiley & Sons, Inc. New York

Smith, W. Brad, Vissage, John S., Darr, David R., and Sheffield, Raymond M., 1997. Forest Resources of the United States, 1997. North Central Research Station, Forest Service, US Dept. of Agriculture, St. Paul, MN.

Harmon, Mark E., 1998. Carbon Re-cycling Presentation, Post Falls, Idaho. Forest Ecologist, College of Forestry, Oregon State University, Corvallis, Oregon.

USDA-Forest Service. 2002. RPA Tablemaker. Interior West Forest Inventory and Analysis. Rocky Mountain Station. www.fs.fed.us/rm/ogden/data_retrieval.html

FORESTRY SUBCOMMITTEE BIOS

Brian Kummet, Nez Perce Tribal Forestry
P.O. Box 365, Lapwai, ID, 83540, (208) 843-7328, briank@nezperce.org

Brian began his career in 1984 as a BLM timber cruiser in Missoula, Mt. The summers of 1985 & 1986 were spent in Dillon, Mt. on a BLM Engine Crew in fire suppression. After graduating in 1986 from the University of Wisconsin at Stevens Point with a B.S. degree in Forest Management, Brian worked as a project forester for the Menominee Tribe in Northeastern Wisconsin from 1986 to 1989. In 1989, Brian was promoted to a timber sale administration forester. He relocated to Idaho in the fall of 1991 to accept the position of reforestation & timber stand improvement (TSI) forester for the Nez Perce Tribe in North Central Idaho. Since reorganizing the program in 1999, Brian is currently the fee lands forester for the Nez Perce.

R. Ladd Livingston, Idaho Department of Lands
3780 Industrial Ave. S, Coeur d'Alene, ID, (208) 666-8624, llivingston@idl.state.id.us

Dr. Livingston is supervisor of the Forest Insect and Disease Section, assigned to the Staff Headquarters in Coeur d'Alene. He provides technical assistance to state and private forest managers across Idaho. Ladd has a Bachelor of Science Degree in zoology and botany from Brigham Young University, and a Ph.D. in entomology and plant pathology from Washington State University. He has 30 years of experience in the state forest insect and disease management program, including practices of prevention, detection, evaluation, and suppression. He also is responsible for gypsy moth detection and control in Idaho and is the state coordinator for the National Forest Health Monitoring program. He has participated on numerous national and international working groups including a North American test of Criteria and Indicators of Forest Sustainability sponsored by the Center for International Forest Research, serving on the Management Team of the USFS Forest Inventory and Analysis / Forest Health Monitoring programs, and is the state representative to National Working Groups for Bark Beetles and Western Defoliators.

Charley McKetta, Forest Econ Inc.
1150 Alturas, Suite 102, Moscow, ID, 83843, (208) 301-4634, forestecon@moscow.com

Dr. McKetta is a consulting forest economist, CEO of Forest Econ Inc, and University of Idaho professor emeritus. His degrees are in forest management, applied physics and forest economics from U. Michigan and U. Washington, with ecological training at the Organizacion de Estudios Tropicales in Costa Rica. He has 30 years of experience in strategic forest planning, timber investment analysis, forest taxation, non-timber valuation and optimization, and analyzing forest sector markets and impacts. He has participated in forest sector development policy with AID, World Bank & 2 international development banks in 4 Latin and 3 south Asian countries. There was former employment as a logger, commercial pilot, and as US Forest Service fire researcher and district recreation officer. He is active in the Society of American Foresters, and the Idaho Forest Owners Association. He manages his own Tree Farm Association certified and stewardship certified 400-acre private forest near Troy, Idaho.

Appendix A

Appendix Table 1: Average per-acre storage of carbon in 11 Western States by state and forest component, 1987 (from Birdsey 1992).

	- - - - - - - - - Pounds of carbon stored per acre in - - - - - - - - -				
State	Total	Trees	Soil	Forest Floor	Understory
Arizona	106,218	44,658	49,227	11,256	1,077
Coloado	124,993	44,405	62,536	16,975	1,077
Idaho	**148,190**	**60,961**	**64,417**	**21,735**	**1,077**
Montana	185,386	67,902	95,732	20,657	1,077
Nevada	83,098	42,658	32,608	6,755	1,077
New Mexico	90,610	30,643	45,790	13,100	1,077
Utah	107,585	38,459	58,225	9,824	1,077
Wyoming	150,012	47,034	81,892	20,009	1,077
Average, Mountain States	124,512	47,090	61,303	15,039	1,077
California	127,372	55,672	53,224	15,042	3,434
Oregon	172,749	64,469	82,976	21,870	3,434
Washington	202,655	83,073	93,911	22,237	3,434
Average Pacific States	167,592	67,738	76,704	19,716	3,434
Average, 22 Western States	136,261	52,721	65,503	16,315	1,720

Appendix B

Detailed Carbon Influences from Forest Insect and Disease Control

Forest insects and diseases attack all parts of a tree including the foliage, branches, twigs, bark and inner bark, wood, cones/seeds and roots. The main ecological role of many of these is nutrient recycling. They are counted as agents of change. This is due to the consumption / utilization of needles and wood and the killing of many trees that can cause distinct changes to forest composition and structure. The feeding activity of the insects and the decay of dead trees by microorganisms contribute to the return of nutrients to the soil with the eventual return of carbon to the atmosphere as carbon dioxide or methane. Because of the threat from these agents to timber, recreation and watershed values, the State of Idaho, Department of Lands has a forest pest management and abatement program which has been established by State code. Forest management practices and control projects aimed at minimizing the impacts of forest insect and disease pests help enhance carbon storage potential by the promotion and maintenance of healthy, fast growing trees and forests and the reduce emission form biomass decay.

The principle aim of the forest insect and disease management program of the Idaho Department of Lands is to prevent problems before they happen. This is accomplished by providing information and training to all forest owners on how to develop and maintain healthy forests, which will in-turn be resistant to attacks by the various insects and diseases. Surveys of damage are conducted annually to detect new outbreaks providing the opportunity to salvage killed or damaged trees. The utilization of these dead or threatened trees contributes to the storage of carbon as wood products are incorporated into utilization projects. When outbreaks occur with damage that exceeds economic or esthetic levels, control projects may be implemented to reduce the impacts on trees and forest stands. Each agent requires its own unique methods of prevention techniques, survey methods and controls. This information is provided to forest owners with field visits and classroom training.

Prevention centers on those silvicultural activities that will produce healthy, vigorously growing forests. An example is the thinning of overstalked stands, both of young, noncommercial trees, and of commercial sized trees. The increased spacing reduces competition resulting in healthier trees that grow more vigorously. Not only are they are resistant to attack by the insects and diseases, but they store carbon faster than the trees of a stagnated, poorly growing forest. Other activities that help prevent damage are the promotion of a stand composition of fast-growing, shade intolerant trees such as pines and western larch. These species are, in general, less susceptible to root diseases which are common in many parts of Idaho and which accounts for very high numbers of killed trees. Another prevention activity is the prompt removal of trees heavily stress or downed by catastrophic events such as fire, winter ice storms, heavy snow or wind. The damaged or downed trees become a breeding site for tree-killing beetles that build up high populations then emerge to kill more trees in the area. They also provide food for wood decaying microbes. The prompt removal of these downed trees both prevents the beetle activity and removes the wood from the decay process, thus contributing in two ways to the reduction of carbon release into the atmosphere. The disposal of slash from logging or natural causes is another practice that can contribute to this phenomenon as there are certain insects that can build high populations in larger pieces of slash and, again, emerge to attack unharvested trees. The down side to this is that slash treatment is often accomplished by burning, a practice that causes an immediate release of carbon into the atmosphere. Some of this can be mitigated through the utilization of smaller sized stems, converting them into products, with commensurate carbon storage.

When outbreaks of pest insects or diseases occur, control activities may need to be implemented. These may include the removal on insect or disease infested trees (sanitation/salvage), or control applied directly to the pest. Examples include the application of pesticides or the development of genetic resistance in the trees themselves. An example of genetic resistance is the development of disease resistant western white pine. This species is very susceptible to an exotic disease, blister rust, which was introduced into the northwest in the early 1900's. A long-term breeding program has lead to the development of resistant trees and the propagation of seeds for reforestation. Outbreaks of defoliating insects, such as the Douglas-fir tussock moth, have been controlled through the aerial application of various pesticides. Bark beetles have been controlled by removal of infested trees or by manipulation of populations with behavior-modifying chemicals that mimic natural compounds produced by the beetles themselves. Sometimes, pests can be controlled biologically through the introduction of parasites or predators that are capable of maintaining populations at low levels, or by the introduction of diseases that are very specific to one or only a very few hosts.

Often, land owners are desirous of participating in programs to prevent or control insects or diseases that kill or damage trees, but are limited in their ability to do so by lack of funds. Increasing the opportunities for monetary returns associated with increasing forest health will help stimulate forest owners be able and willing to participate in these activities. Finding new uses, and the demand, for small diameter logs that result from thinning is an example. Government sponsored cost share programs would also help this cause. There are several programs currently available from the federal government; however, they are also limited by funding. Sales of carbon credits by forest owners also have potential for providing increased returns from forested acres, stimulating increased participation in all programs.

These subject areas, increasing forest health for resistance to insects and diseases, controlling pests, and increasing funding for landowner participation have the potential to make significant contributions to carbon sequestration.

13.3 APPENDIX 3 - BIOFUELS CONTRIBUTION TO CARBON SEQUESTRATION

BIOFUELS CONTRIBUTION TO CARBON SEQUESTRATION

Introduction

Idaho has a large agricultural and forestry economic base and a potential to sequester carbon. In addition to promoting agricultural and forestry management practices to increase the sequestration of carbon there are opportunities to offset carbon emissions from fossil fuels by utilizing biofuels.

The State has a history in producing fuel grade ethanol and biodiesel research. Today there are two small fuel grade ethanol plants owned by the J.R. Simplot Company producing fuel grade ethanol from potato peel and chips. These plants having been producing ethanol since the mid-80's. There are other entities considering building several large modern ethanol plants in the near future.

The University of Idaho Department of Biological and Agricultural Engineering has been investigating the feasibility of utilizing plant-derived oils as fuels in compression ignition engines. Demonstration projects have ranged from using raw unrefined oil as fuel to ASTM grade biodiesel powering an 18-wheeler with a 50:50 blend of biodiesel and No. 2 diesel for 200,000 miles.

Analysis

<u>Ethanol</u>

Presently the blending of ethanol with gasoline occurs less than 1 per cent of the time in Idaho. It should be noted that there is a marketing incentive to use ethanol in gasoline. It is an exemption of the excise tax for the use of 10% ethanol blends or E-10. There are no incentives for other biofuels.

The fuel usage for Idaho in 2001 is given in Table 1. If the State were to blend 10 per cent ethanol in the gasoline pool, there would an offset of approximately 400,000 tons of carbon dioxide due to the reduction in burning fossil fuels. This calculation takes into consideration that for every gallon of ethanol produced by fermentation there are 6.3 lb of CO2 produced. It was also assumed that a gallon of gasoline produces approximately 19.5 lb of carbon dioxide when consumed in an internal combustion engine.

Table 1. Idaho 2001 Fuel Usage*

Fuel	Gallons (000,000)
Gasoline	603
Diesel	222
Dyed diesel	124

* Idaho Tax Commission

<u>Biodiesel</u>

Biodiesel is the result of chemically modifying plant or animal oils by replacing the glycerin molecule in the triglyerides with an alcohol. The alcohols of choice are either methanol or ethanol. It was assumed that since diesel contains 12.5 percent more energy per pound than gasoline that diesel would produce approximately 24 pounds of carbon dioxide per gallon.

It can be seen in Table 1 that Idaho uses approximately 346 million gallons of on-road and off-road diesel fuels.

For this analysis it will be assumed that there would be a 20 per blend of biodiesel in the diesel pool. The alcohol used in the manufacturing influences the benefit of blending biodiesel. If it were assumed that ethanol was the alcohol of choice, then quantity of carbon dioxide offset would be approximately 784 thousand tons. In contrast if methanol were the alcohol of choice, then the offset would be approximately 730 thousand tons of carbon dioxide.

A summary of the benefits for using certain biofuels for offsetting carbon dioxide produced from burning fossil fuels is given in Table 2.

Table 2. Carbon Dioxide Offsets for selected Renewable Fuels

Fuel	CO2 Offset (000 tons)
Ethanol (E-10)	400
Diesel (B-20)	730 if methanol were used
	784 if ethanol were used
Total	1,100 to 1,200

Discussion

Utilizing biofuels to create carbon credits has the potential of increasing the benefit per acre of agricultural land beyond that of improving the land management practices. For example if it were assume that E-10 were utilized in the state gasoline pool it would require approximately 60 million gallons of ethanol. If it were assumed that the grain used to produce the ethanol had a yield of 130 bushels per acre and that the yield per bushel to produce ethanol was 2.65 gal, it would require about 175,000 acres of land to produce the grain to produce the ethanol. If the offset for ethanol (Table 2) were distributed over those acres, the offset benefit per acre would be about 2.27 tons of CO2 per acre.

The benefit per acre will vary with the yield per acre for the grain and by the yield per bushel for producing the ethanol.

A similar analysis for biodiesel shows that the offset for carbon dioxide per acre is 1.13 ton/acre. This is based on the following assumptions: 10 ton of oil seed per acre and 10 gal of oil per ton. Due to the diverse agriculture within the State, the benefits of offsetting carbon dioxide will vary with crop yield.

The use of biofuels to offset carbon dioxide from fossil fuels is an effective means to reduce the production of greenhouse gases. The use of biofuels has many times the benefit described elsewhere for improving land management practices to sequester carbon.

For the State to promote the sequestering of carbon, it should consider a comprehensive biofuels program as an effective means to accomplish this.

Presently there is an ethanol incentive, which is an exemption of the excise tax on gasoline. This program should be expanded to cover other bio-based fuels such as biodiesel. Also, it should be changed to be a producer incentive, to promote the production of biofuels within Idaho.

Such a program should be comprehensive to cover future developments in this field so that the legislature is not approached with requests for programs promoting new technologies as they are developed.

Such a comprehensive program should address the percentage of biofuels utilized in the parent fuel blend. For example, Brazil has a national program to promote the use of its agricultural production in biofuels. Brazil promotes the use of sugar in the production of fuel grade ethanol. On the consumption side the blend ratios vary from the mid-teens to 22 percent ethanol.

The Energy Policy Act of 1992 (EPACT) requires that private, state, and federal fleet operators purchase vehicles that can run on alternative fuels. One those options is to purchase vehicles that can run on E-85 or 85 percent ethanol and 15 percent gasoline. The automobile manufactures are producing certain vehicle models that are E-85 compatible for sale to the public. How should that fuel be considered?

The percentage of biodiesel in diesel fuel blends can vary from zero to 100 percent.

For examples of new technologies, there is a small company in northern Idaho that is developing the fuels and associated technologies to run engines on ethanol fuels that are approximately 70 percent ethanol and 30 percent water. Such fuel and fuel systems greatly reduce harmful emissions and offset greenhouse gases. Also, there is great interest and effort being expended to convert cellulose into ethanol. Such technology could be a tool to assist with the management of Idaho forests by providing an outlet for salvage trees and thinnings.

As part of a comprehensive biofuels program, the legislature should review the franchise agreements between major oil companies and the local retailer, which discourage or prohibit the use of biofuels. Presently some agreements prevent the use of fuel additives not approved by the supplier even though those companies use ethanol blends in many areas of the country that have oxygenated fuel requirements. Are those agreements in the best public interest if they are a hindrance to developing public policy to promote carbon sequestration?

In addition to blending biodiesel with diesel fuels, ethanol can be blended with diesel fuels in the 5 to 15 percent range with the use of an emulsifier.

It can be seen that there are many opportunities to utilize biofuels in Idaho. Such use would improve air quality and offset greenhouse gases from fossil fuels.

To address the economic benefit of promoting means to sequestering carbon dioxide and reduce greenhouse gases, the legislature should request the appropriate economic study be conducted.

Recommendations

Develop a comprehensive biofuels incentive program for Idaho that considers:

- All bio- or renewable fuels.
- The percent of biofuel blended in the parent fuel.
- Promote ethanol in the manufacturing of biodiesel.
- Changing the present incentive to a producer's credit.
- Future technologies.
- Question fuel distribution agreements, which inhibit or discourage the use of biofuels.
- Commission a study to address the economic benefit to Idaho of sequestering carbon.

13.4 APPENDIX 4 – PNDSA SOIL CARBON SEQUESTRATION SYNOPSIS

A Synopsis of the PNDSA Soil Carbon Sequestration Lease Contract

History in the Making

On April 15, 2002 a contract was signed between the Pacific Northwest Direct Seed Association [PNDSA], a producer based organization, and Entergy, an energy producing company based in New Orleans Louisiana serving costumers in Louisiana, Texas and Arkansas. The contract is for a ten [10] year lease of CO2 credits generated through the practice of direct seeding crop land in the Pacific Northwest [PNW]. An annual trade of 3,000 tons CO2 is contracted between PNDSA and Entergy for the next ten years for a total of 30,000 tons CO2. PNDSA was paid $75,000 to aggregate a base of growers for this sequestration project. PNDSA then contracted with 77 grower members representing 6,470 production acres to meet its obligation with Entergy. The grower is being paid to direct seed a designated acreage for the next ten years, which will sequester 55/100ths [.55] tons of CO2 per acre per year. The acreage will be monitored and verified as direct seeded by local NRCS Conservation Districts, which have contracted growers participating. The contract meets the Kyoto protocols involving additionality, duration, permanence and leakage.

The PNDSA was started in January 2000 by a group of producers and university researchers from the three-state region known as the PNW (Oregon, Idaho and Washington). The PNDSA is a grower driven organization whose mission is to facilitate the development and adoption of direct seed cropping systems through research coordination, funding and information exchange. The board of directors is made up of four directors from each state. The three state land grant universities are represented on the board of directors as ex-officio members. Within the framework of our mission we developed a working relationship with Environmental Defense Fund [now called Environmental Defense]. That relationship resulted in a one-page offer sheet being solicited from PNDSA to lease CO2 credits to emitters. Environmental Defense [ED] took the one page offer and circulated it among a consortium of energy companies that had made a commitment to ED to reduce their emissions. Entergy submitted a counter offer to PNDSA and the negotiations began. The negotiations focused on creating a contract that would be verifiable under the Kyoto protocol if and when it became ratified. Those articles are now stated as Article 3.3 and 3.4 and include *additionality, permanence, duration* and *leakage*. *Additionality* means that credits generated must be additional to any changes in carbon that would have occurred under a "business as usual" scenario. *Permanence* refers to the length of time carbon is sequestered and maintained in a sink such as agricultural soil. *Duration* refers to the length of the contract. *Leakage* concerns the issue of project activities causing economic agents to take actions that would increase Green House Gas [GHG] emissions elsewhere. These negotiation issues were resolved with input from ED and other resources.

After considerable research and interaction with other global partners also studying this issue, the PNDSA elected to pursue leasing versus selling of carbon credits. The lease allows temporary control of the management of the land by the energy company. The sale of a C-credit would allow control in perpetuity, and the sale raises a number of legal issues concerning obligations, measurement and performance that are not clearly understood by either potential sellers or buyers. The lease allows the grower to retain ownership of the C-credits at the end of the contract. The lease in the opinion of PNDSA is a win-win for the environment and the contract parties. The emitter is forced to reduce emissions, create an internal sequestration system or renegotiate to continue leasing sequestration systems from the contracted growers. The ultimate goal of PNDSA in this contract is to stimulate research to develop a whole-farm accounting of carbon and carbon equivalent changes occurring as a result of direct seed cropping systems. Our vision is to have a yield of carbon equivalents for each farm based on the many environmental and management decisions that the farmer employs. That farmer could then market C-credits they earn or sequester.

After completing and signing an agreement with Entergy, the PNDSA developed an agreement with its grower members to meet the obligations stated within the Entergy contract. That agreement contained the definition of direct seed that would be used to verify sequestration per our agreement. The contract also included other necessary requirements and penalties to protect PNDSA. The PNDSA has the ability to solicit additional acres if existing producer contracts go into default. We restricted our growers to a maximum of 100 acres to spread the risk of default and to protect the producers from committing too many acres too early in the development of the carbon sink market. It is widely accepted that the price paid per ton of CO_2 sequestered will be impacted upward with any regulated emission controls. Grower contracts were completed in November 2002 and money was transferred to the producers. PNDSA is presently developing a verification agreement with local Conservation Districts who have grower contracts within their districts (The average number of producers per district is four).

This project highlights the ability of the private sector to manage an environmental change without federal mandates. The United States is involved in political debate, industry discussion and market formation to deal with GHG reductions. The PNDSA is very proud to be an early innovator in the implementation of a leasing strategy to aggregate agricultural producers in the development of a market for C-credits. Our relationship with Entergy and Environmental Defense is unprecedented in the U.S. agriculture. We commend each of those entities for their willingness and commitment to assist us in developing an agriculture production system that benefits society, the environment and producers. Environmental marketing of direct seed benefits can play a major role in economic sustainability of American Agriculture.

13.5 APPENDIX 5 – PRACTICE/ACTIVITY RATINGS

PRACTICE/ACTIVITY RATINGS TABLE

Table 1. Practice/Activity Ratings

Carbon-GHG Practice	Accept-ability	Effectiv-eness	Cost	Implemen-tation	Operation & Maintenance	Monitoring	Verification	Ancillary Benefits	SUM OF RATINGS	SUM W/O COST
Windbreaks and shelterbelts	-1	2	-2	2	2	3	2	3	11	13
Reforestation	2	1	-2	2	1	2	2	2	10	12
Grassland cover	0	2	0	1	2	1	0	2	8	8
Short rotation woody crops	-2	3	-2	1	1	2	2	1	6	8
Riparian forest buffers	-2	2	-2	1	1	2	1	3	6	8
Riparian conservation/restoration	-2	2	-2	1	1	2	1	3	6	8
Residue management (no-till, direct seed)	1	1	0	1	1	2	-1	2	7	7
Afforestation, marginal pasture	0	3	-1	0	1	1	1	1	6	7
Alley cropping	-2	1	-1	1	0	3	2	2	6	7
Fire management	1	1	-2	1	1	2	-2	2	4	6
Afforestation, marginal cropland	-1	3	-1	0	1	1	1	1	5	6
Biofuels production	1	2	-3	1	-1	2	1	0	3	6
Grass waterways	1	2	0	1	1	1	-1	0	5	5
Range and pasture planting	1	0	-1	3	1	2	-2	0	4	5
Afforestation, pivot corners	-1	3	0	0	1	1	1	0	5	5
Cropland biomass energy source	-1	2	-2	0	-1	2	1	1	2	4
Afforestation, poorly stocked forest	1	2	-2	-1	-1	0	0	2	1	3
Afforestation, non-stocked forest	1	2	-2	-1	-1	0	0	2	1	3
Regeneration harvesting	0	0	-2	1	1	1	-2	1	0	2
Pest management	0	0	-2	1	1	0	-2	2	0	2
Forestland biomass energy source	-2	2	-3	-2	0	1	1	2	-1	2
Cover crops	-1	1	0	1	-1	1	-1	1	1	1
Crop residue burning - alternative uses	-1	2	-1	-1	-1	0	0	2	0	1
Stand density control	-1	0	-2	1	1	1	-2	1	-1	1
Salvage	-1	0	-2	1	1	1	-2	1	-1	1
Stand composition control	-2	0	-2	1	1	1	-2	1	-2	0
Wetland construction/enhancement	-1	1	-3	-2	-1	2	-1	2	-3	0
Reduced methane emissions from ruminant livestock	0	1	0	1	1	-1	-2	0	0	0
Biogas recovery - digesters	-2	1	-3	-1	-1	1	1	1	-3	0
Controlling rotation length	-2	0	-1	1	1	0	-2	1	-2	-1
Nutrient management	-1	0	2	0	0	1	-2	0	0	-2
Crop residue burning - alternative burning techniques	-2	1	-2	-2	-2	1	0	1	-5	-3
Prescribed grazing	-2	0	-2	0	-1	0	-2	1	-6	-4
Edaphic (site) modification	-2	0	-2	0	0	-1	-2	1	-6	-4
Rate -3 (negative) to 3. Where -3 is considered poor, low, high cost, etc., where 3 is excellent, high, or low cost. For example, a -2 rating would be very low chance of a practice being accepted, whereas a 2, might be considered a good chance, and so on. Another example: effectiveness is high (rating = 2) or implementation is difficult (-2).										

13.6 APPENDIX 6 – PRACTICE/ACTIVITY EFFECTIVENESS

PRACTICE/ACTIVITY EFFECTIVENESS – Subject to change with further analysis.

Table 1. Practice/activity Effectiveness, State-wide

Practice	Total available acres, or number	Minimum % Applied	Maximum % Applied	Range of Effectiveness ($MTCO_2e$/ac or #/y)	Selected value (MTco2e/ac or #/y)	Minimum CO_2e MT/y	Maximum CO_2e MT/y
Nutrient management (N_2O reductions)	4541300	30%	100%	0.05 - 0.8	0.30	408717	1362390
Cropland biomass energy source (wheat, barley, bluegrass)	1905000	5%	50%	0.52	0.52	130915	1309152
Afforestation, marginal cropland (13% of cropland)	600900	2%	15%	247/20y	12.30	147821	1108661
Biofuels production, ethanol (wheat, barley, corn acres)	1915000	5%	35%	1.2-2.6	1.63	156073	1092508
Residue management (no-till, direct seed) (60% of all crop)	2724780	10%	60%	0.2 - 0.7	0.50	136239	817434
Short rotation woody crops (50% of irrigated)	1400000	1%	5%	8.3-11.6	8.00	112000	560000
Crop residue burning alternative uses or techniques (burned ac)	150000	40%	100%	reduced by 100%	3.31	198722	496804
Grassland cover (similar to CRP) (20% cropland)	900000	15%	100%	0.4 - 0.7	0.50	67500	450000
Windbreaks, shelterbelts (4%/acre) 40% of cropland)	1816520	1%	40%	2.2-24.8	10.00	7266	290643
Cover crop (used 30% of time in rotation) (60% of cropland)	2724780	20%	60%	0.3-0.51	0.40	65395	196184
Nutrient management, N production CO_2	4541300	10%	100%	0.039	0.04	18165	181652
Afforestation, pivot corners (400 ea, 12.5%/acre)	640000	0.5%	30%	2.7-5.3	3.50	1400	84000
No-till, direct seed - N_2O field emissions (60% of cropland)	2724780	10%	60%	0.05	0.05	13624	81743
No-till, direct seed - CO_2 fuel emissions (60% of cropland)	2724780	10%	60%	0.01 - 0.02	0.01	2725	16349
Biofuels production, biodiesel (canola acres)	22500	5%	50%	0.6 – 1.1	0.80	900	9000
Grassed waterways (1%/acre) (non-irrigated cropland)	1725694	5%	50%	0.48	0.48	414	4142
Prescribed grazing, rangeland (private, state)	3580233	25%	75%	0.2 - 0.5	0.20	179012	537035
Range planting (private, state)	3580233	2%	20%	0.2, 1.1-1.8	0.50	35802	358023
Afforestation, marginal pasture land (20% of total pasture)	273100	2%	15%	138/20y	6.90	37688	282659
Pasture planting (private, state)	1365500	5%	25%	0.2, 1.1-1.8	0.50	34138	170688
Prescribed grazing, pastureland (private, state)	1365500	10%	50%	0.2 - 0.5	0.20	27310	136550
Afforestation, poorly stocked forest land (private, state)	3493040	2%	10%	92/20y	4.60	321360	1606798
Afforestation, non-stocked forest land (private, state)	1097831	2%	10%	118/20y	5.90	129544	647720
Forest biomass energy source (forest floor litter)	3493040	1%	10%	1.80	1.80	36535	365355
Riparian conservation/restoration (acres) (private land,6 ac/mile	163308	1%	35%	118/20y	5.90	9635	337231
Riparian forest buffers (nonforested land, 6 ac/mile)	142155	1%	5%	3.2-6.4	6.90	4904	49043
Riparian conservation/restoration (acres) (state land,6 ac/mile	14280	1%	35%	118/20y	5.90	843	29488
Wetland construction and enhancement (1000 @ 10 ac. ea)	10000	5%	75%	0.2 - 0.5	0.35	175	2625
Biogas recovery, (CH_4), digesters, (# cows)	377000	20%	50%	reduced by 80%	3.91	294974	737434
Reduced CH_4 emissions from dairy livestock (# cows)	377000	20%	50%	reduced 3-20%	0.10	163882	409705
Reduced CH_4 emissions from dairy replacements, 12-23 mo.	175000	20%	50%	reduced 3-20%	0.10	154674	386685
Reduced CH_4 emissions from bulls	40000	20%	50%	reduced 4-30%	0.15	80968	202419
Reduced CH_4 emissions from steers	360000	20%	50%	reduced 4-30%	0.15	44982	112455
Reduced CH_4 emissions from beef livestock	493000	20%	50%	reduced 4-30%	0.15	22152	55380
Reduced CH_4 emissions from beef replacements, 12-23 mo.	85000	20%	50%	reduced 4-30%	0.15	39359	98398
Reduced CH_4 emissions from sheep	260000	20%	50%	reduced 4-30%	0.15	14280	35700
Reduced CH_4 emissions from goats	4600	20%	50%	reduced 4-30%	0.15	7426	18564
Reduced CH_4 emissions from swine	240000	20%	50%	reduced 4-30%	0.15	82	205
Biogas recovery, (N_2O), digesters, (# cows)	377000	20%	50%	reduced by 80%	0.06	4715	11787

13.7 APPENDIX 7 – EQUATIONS, CALCULATIONS

EQUATIONS – CALCULATIONS

The following equations and process are used to estimate carbon sequestration or reduced emissions from the application of specific practices or the implementation of activities:

N_2O emissions from cropland fields, soil, nutrient (nitrogen) management:

While improved nutrient management provides multiple benefits, there is much uncertainty as to the amount of nitrogen loss that may be reduced from nutrient management, one estimate of from Lal et al, 1999, ranges from **0.22 to 0.74 MT CO_2e**. For Idaho, 0.3 MT CO_2e will be used to estimate a statewide potential. See IPCC and EPA methodology to estimate soil emissions, then would apply practice for reduction estimate.

If we want to first estimate N emissions, then a series of equations provided by IPCC 1996 could be used, however, the only variables that will significantly reduce total N_2O loss is EF_2 (emission factor), crop acres, and manure applied (N content and quantity). EF_2 is effected by tillage, cultivation, thus no-till should reduce N losses substantially, if EF_2 variable is determined for no-till.

Cropland N_20 emissions from soils		
N2Odirect =	[(Fsn + Faw + Fbn + Fcr) x EF1] + Fos x EF2	
N2Odirect =	35164033	kg N/yr
EF1	0.0125	kg N2O-N/kg N input
EF2	5	kg N2O-N ha/yr
Fos	1710432	total crop ha
Faw	96009600	= total Fawd + Fawb
Fawd	21489000	= Nex x (1-(Fracfuel + Fracgraz + Fracgasm)) kg N/yr - dairy
Fawb	74520600	= Nex x (1-(Fracfuel + Fracgraz + Fracgasm)) kg N/yr - beef
Nex	100	kg N/yr total dairy manure/yr
Nex	70	kg N/yr total beef manure/yr
Dairy pop.	377000	number of dairy cows in 2001
Beef pop.	1613000	number of cattle, minus dairy, in 2001
Fracfuel	0	kg N/yr
Fracgraz	0.23	kg N/ kg N excreted- dairy
Fracgraz	0.14	kg N/ kg N excreted- beef
Fracgasm	0.2	kg NH3-N + Nox-N/kg of excreted
Fbn	4402305.9	= 2 x Cropbf x Fracncrbf kg N/yr
Fracncrbf	0.03	kg N/kg dry biomass
Fcr	325377980	= 2 x [Cropo x Fracncro + Cropbf x Fracncrbf)] x (1-Fracr) x (1-Fracburn) kg N/yr
Cropo	21764231571	kg dry biomass non-fixing crops
Fracncro	0.015	kg N/kg of dry biomass
Cropbf	73371765	kg dry biomass/yr, legume seed yield + soybeans (alfalfa seed, beans only here)
Fracr	0.45	kg N/kg crop-N, residue removed from field
Fracburn	0.1	kg N/kg crop-N, fraction of residue burned field
Fsn	61.2	= Nfert x (1-Fracgasf) kg N/yr
Fracgasf	0.1	= kg NH3-N + Nox-N/kg of N input
Nfert	68	kg N/yr (150 lbs/ac average)

Reduced CO_2 diesel emissions by reducing N fertilizer production, through less N used,
See Iowa fertilizer and tillage reduction case study:

12 million acres 145 reduced to 127 lbs N/acre. 18 lbs N /ac or 216 million lbs saved, (97,977 MT), 13% reduction in N applied. 3.6 gallons diesel reduced (1 gallon diesel used /5 lbs N produced). 24 lbs C/gallon diesel used (24 lbs CO_2 or 0.011 MT CO_2). Thus **0.039 MT CO_2/ac/yr** reduced.

145 – 127 lbs/ac = 18 lbs/ac/yr saved
(18 lbs/ac/yr) / (5 lbs N/gallon) = 3.6 gallons/ac/yr
(3.6 gallons x 24 lbs CO_2) / 2204.6 lbs/metric ton = **0.039 MT CO_2/acre/yr**

This emission offset was included in the nutrient (nitrogen) management state-wide estimate (0.3 MT CO_2).

Reduced CO_2 diesel emissions through less tillage, as with no-till and direct seed,
See Iowa fertilizer and tillage reduction case study:

12 million acres used residue management (conservation tillage, no-till), 127,000 to 257,000 MT CO_2e, where 1-2 gallons diesel saved per acre, 24 lbs CO_2/gallon diesel used, thus **0.01 to 0.02 MT CO_2/ac/yr.**

(1 gallon x 24 lbs CO_2) / 2204.6 lb/metric ton = **0.01 MT CO_2/ac/yr**
(2 gallon x 24 lbs CO_2) / 2204.6 lb/metric ton = **0.02 MT CO_2/ac/yr**

Anaerobic, dairy lagoon methane (CH_4), emissions - See EPA-Annex L

Total metric tons of methane that could possibly reduced from bioenergy facilities on the larger dairy facilities or from centralized facilities, supplied by smaller dairies, is about 0.74 MMT CO_2e. The assumptions in the calculation are as follows:

The total number of cows on facilities with > 1000 head (population) = 377,000
Average total volatile solids (VS)* (kg/head/y) = 3325 (Idaho rate)
Maximum methane generation potential (B_o)* = 0.24 CH_4/kg.
Weighted methane conversion factor (MCF) = 0.4408
Conversion factor of m^3 CH_4 to kg CH_4 (kg CH_4/m^3 CH_4) = 0.662

The global warming potential (GWP) for CH_4 is 21 (50yrs)

Calculation derived from USEPA 2002 and IPCC 1996.

Methane equation: Methane = (population x VS/y x B_o x MCF x 0.662)/1000*21 GWP CH_4/CO_2e:

(377,000 x 3325 x 0.24 x 0.4408 x 0.662)/1000 kg/MT x 21 CH_4/CO_2e = 1.8 MMT CO_2e. If digesters are only 80% effective and only 50% of large dairies install digesters, then the result is about 0.74 MMT CO_2e.

Anaerobic, dairy lagoon nitrous oxide (N_2O) emissions See EPA-Annex L

The use of digesters would also capture N_2O, which is similar conditions apply with dairy facilities. The equation to calculation total N_2O emissions for state dairy livestock is:

The total number of cows on facilities with > 1000 head (population) = 377,000
Total Kjeldahl nitrogen excreted annually per head/day (N_{ex})= 0.44 kg (161 kg/365 day year)
Weighted nitrous oxide emission factor ($EF_{animal, state}$) = 0.001 kg N_20-N/kg N

Conversion factor of N_2O-N to N_2O = 44/28 = 1.57
The GWP conversion of N_2O is 310 (50 yrs).

Calculation from USEPA 2002 and IPCC 1996:

Nitrous oxide equation: N_2O = (population x N_{ex} x $EF_{animal,\ state}$ x1.57)/1000*310

(377,000 x 0.44 * 365 x 0.001 x 1.57)/1000 x 310 GWP N2O/CO2e = 29,468 MT CO_2

If 50% of the dairy cow population N_2O emissions were captured by digester systems, with 80% efficiency, then approximately 11,787 MT CO_2e may result.

Biofuels fossil fuel emission offset – See Biofuels subcommittee report.

Ethanol:

Table utilizes 2001 NASS for Idaho.

Table 1. Estimated Ethanol Production with Existing Crop Base

Crops	2001 acres	2001 yield - bushels	ethanol acres	gallons ethanol	CO2e @ 13.2lb/gal or .0066 MT	metric ton CO2e/acre	% acres of total acres
corn, grain	45000	150	11250	4471875	29514	2.62	2%
barley	670000	75	167500	26381250	174116	1.04	35%
wheat	1200000	71	300000	55380000	365508	1.22	63%
totals	1915000		478750	86233125	569139	Ave. 1.63	100%

Gallons ethanol produced from 1 bu of corn = 2.65
Gallons ethanol produced from 1 bu of wheat = 2.6
Gallons ethanol produced from 1 bu of barley = 2.1

Gasoline produces 19.5 lbs CO2, diesel 24 lbs, ethanol 6.3 lbs. Thus 13.2 lbs reduced when gasoline replaced with ethanol. To achieve a specific quantity of ethanol per year, adjust acres:

Table 1. Adjusted acreage to reach 1 million gallons of ethanol

	% of total	new total crop acres	25% of acres	gallons ethanol	CO2e @ 13.2lb/gal or .0066 MT	metric ton CO_2e/acre
corn, grain	16%	306400	76600	30448500	200960	2.62
barley	28%	539300	134825	21234938	140151	1.04
wheat	56%	1069300	267325	49348195	325698	1.22
totals	100%	1915000	478750	101031633	666809	Ave. 1.39

Biodiesel:

Canola acres in 2001 were 22,500, where yields were 0.72 MT of oil seed per acre. One MT of canola oil seed produces 110 gallons of diesel. If 50% of these total canola acres (11,250 acres) were used for biodiesel production, where 1 gallon of biodiesel provides a 17.7 lb CO_2 (or 0.008 MT) offset per gallon of diesel fuel, then approximately 9,000 MT of CO_2 offset is generated.

Crop residue burning alternatives – See IPCC Guidelines… 4.4

To calculate what amount of emissions may be reduced, depends on the amount currently lost due to burning. Factors used in determining emissions are:

Amount of crops produced with residues that are commonly burned,
Ratio of residue to crop product,
Fraction of residue burned,
Dry matter content of residue,
Fraction oxidized in burning,
Carbon content of the residue.

The equation used: Total carbon released = sum of:
annual production of crop (metric tons)
X ratio of residue to crop product (fraction)
X average dry matter fraction of residue (MT dry matter/MT biomass)
X fraction actually burned (amount residue burned of total residue)
X fraction oxidized
X carbon fraction (MT carbon/MT dry matter)

The ratio of residue to crop product will be replaced with the average amount of residue per yield, in bushels, for Idaho crops. For instance, an average of 90 and 70 pounds of residue remains per bushel of wheat and barley respectively.

Once the carbon released from field burning of agricultural residues has been estimated, the emissions of CH_4, CO, N_2O, and NO_x can be calculated based on emission ratios:

CH_4	0.005; Range 0.003 - 0.007	N_2O	0.007; Range 0.005 - 0.009
CO	0.06; Range 0.04 - 0.08	NO_x	0.121; Range 0.094 - 0.148

The calculation for trace gas emissions from burning is summarized as follows:

CH_4 Emissions = Carbon Released x (emission ratio) x 16/12
CO Emissions = Carbon Released x (emission ratio) x 28/12
N_2O Emissions = Carbon Released x (N/C ratio) x (emission ratio) x 44/28
NO_x Emissions = Carbon Released x (N/C ratio) x (emission ratio) x 46/14

Enteric fermentation, methane emissions – See IPCC Guidelines… 4.2

According to industry estimates, methane emissions could be reduced by up to two percent per year if the above practices are employed. If the above-discussed methods were used on all of Idaho's dairy and beef cattle populations, then the maximum amount of methane reduced may be 1.3 MMT CO_2e (50,386 dairy + 2,169 beef). The IPCC 1996 Tier one calculation follows:

[Emission factor (kg/head/yr) x population (head) / (1000 kg/MT)] x 2.75 (CH_4/CO_2) = total methane emissions for state.

The IPCC 1996 guidelines provide that for dairy cows in temperate climates, such as Idaho, 54 kg/head/yr emission factor, and 2 kg/head/yr for non-dairy (beef) cattle. If the above methods resulted in a 20% reduction of emissions, then 0.5 MMT CO_2e (25,193 dairy + 1,085 beef) may be reduced. If 20% of sheep, goats, and swine populations were involved in methane reductions, about 22,000 MT CO_2e could be reduced.

For future estimates, that may be a part of a carbon sequestration, emissions reduction market or program, it is recommended that the Tier 2 calculation approach be used to estimate methane reductions due to practice methods. This calculation, which involves numerous equations, can be found in IPCC, 1996.

Cropland biomass to bioenergy – Refer to Chariton Valley Biomass Project

If Idaho wheat, barley, and bluegrass residues were utilized in the production of bioenergy, a substantial amount of CO_2e emissions could be reduced. The Chariton Valley Biomass Project in Iowa showed that by utilizing switchgrass, about 0.52 MT CO_2e/y emissions could be reduced, replacing a percentage of coal in a power plant. Grass and coal would be cofired, where 12.5 tons per hour would be used along with the coal. Where Idaho's wheat, barley, and bluegrass production and remaining residue is less, by about ½ of switchgrass, an gross amount of CO_2 emissions could be reduced in cofiring plants. This estimate is not dependent on existing or potential energy or similar plants, but on the capability and available amount of residues.

As discussed above regarding reducing crop residue burning, 16.2 million MT CO_2e/y could be reduced. If these residues, replacing similar amounts of fossil fuels, such as coal, could reduce CO_2 by about 0.13 to 1.3 million MT (5% to 50% use of available residue – see Table 1). The use of wood wastes in cofirng plants would produce a greater amount of CO_2 reductions on a per tonnage basis, where the density of wood is much greater than straw or grass residue. The heating capability of coal is higher than wood, possibly 1 to 3 times as high. Depending on the coal type, or other fossil fuels used, 1 to 3 times more biomass residue may need to be used for equivalent power or heat generation. Where coal most available to Idaho (bituminous), produces about 20 or more million Btu's per ton, where wood generates about 17.2 million Btu's per ton. The comparison of wood to coal for heat generation shows that though wood is slightly less, the value wood as an alternative to coal is substantial. Emissions are substantially offset as well, where additional emissions of compounds are eliminated or reduced.

Table 1. Crop Residue for Bioenergy, assume 0.52 MT CO2/MT biomass fossil fuel emissions offset

Crop	2001 Acres	2001 Yield bu/a	Residue kg/bu	Usable Biomass MT	CO2e MT 5% acres	CO2e MT 50% acres
Wheat	1200000	71	40	3408000	88608	886080
Barley	670000	75	32	1608000	41808	418080
Bluegrass	35000	181-454 kg/ac	320 kg/ac	11200	291	2912
Totals	6495870		50% useable	10054203	273977	2739768

Forest floor biomass to bioenergy – Refer to Appendix 2

The amount of wood on forest floor is about 1 MT C/acre in a poorly stocked or non-stocked forest (see Appendix 2). If only 50% of forest floor wood litter is collectable for bioenergy use (0.5 MT C/ac or 1.8 MT CO_2e) and 0.52 MT CO_2 is offset per MT of biomass (wood), then MT CO_2/acre of offset may result. If a total of 10% of those poorly stocked forest lands (about 350,000) were to provide wood for fossil fuel replacement, then about 0.3 MMT CO_2e could be offset.

Note: If the wood used to burn in place of fossil fuels, such as coal, and the CO_2 is not captured at the plant, sequestered elsewhere, the previous amount of CO_2 sequestered within the wood may have to be discounted to determine the actual net CO_2 offset.

Windbreaks, shelterbelts

Assume that windbreaks/shelterbelts are at least 50 ft wide. For a 50acre square field, side length is 1475 feet.

$$\frac{1475 \text{ x } 50 \text{ ft}}{43560 \text{ ft}^2/\text{acre}}$$ = 1.7 acres, use 2 acres per 50 acre field, or 4% of field planted to trees, shrubs (2 / 50)

Grassed waterway

Assume that a waterway is at least 15 feet wide, use 20 ft. For a 50 acre field, side length is 1475, use this for estimated length of waterway within field. Similar to windbreak/shelterbelts:

$$\frac{1475 \text{ x } 20 \text{ ft}}{43560 \text{ ft}^2/\text{acre}}$$ = 0.7 acres, use 1 acres per 50 acre field, or 2% of field planted to grass (1 / 50)

The assumption is made that only non-irrigated cropland acres are available for grassed waterways. If only 50% of these acres incorporated grassed waterways, then 4,142 MT CO_2e is offset.

Grassland cover

If there are 4.5 million acres of cropland, but only 900,000 are really available for conversion to grassland, and then only 25% of those acres are converted to grasslands (225,000), then about 0.4 MMT CO_2e could be offset. 0.5 MT CO_2e/ac is used here to estimate total potential offsets.

Riparian forest buffer, non-forested areas

Assume that a buffer is at least 100 feet on one side of stream, planted within floodplain and possibly on adjacent uplands. Assume, then that for only one side of stream, per mile of stream, there are 12 acres per mile. Assume that only 75% of the stream is capable of supporting forest buffers, therefore 9 acres per mile.

$$\frac{5280 \text{ ft/mile x } 100 \text{ ft x } 0.75}{43560 \text{ ft}^2/\text{acre}}$$ = 9 acres per mile stream, one side.

Assume that are 3.2 million acres of private/tribal forested acres and 1.3 million acres of state forest land which are under Forest Practices Act rules. These lands are assumed to have or will have adequate riparian protection, possibly not eligible for carbon market funds, so they will not be considered in this estimate at this time. Using a rough estimate that 16.7 million acres of private and tribal land, then only 19% of private and tribal lands are in forest. Assume then only 19% of streams are forested, therefore under forest practices act, and will not be considered for additional sequestration with riparian forest buffers at this time. Utilizing the state Hydro100 GIS shape file provided through the state ftp GIS website, that there are about 31,590 miles of stream on non-forested lands and 7,410 miles within forested lands. Assume that only ½ of those miles are perennial and/or have potential for riparian buffers and adequate available water. Many drains, canals, and other water bodies show up within the Hydro100 layer, not labeled, and are not considered natural streams, therefore will not be considered here for riparian forest buffers.

Private, state, tribal non-forested stream miles = 31,590 miles x 50% x 9 acres/stream mile = 142,155 acres

If on average, riparian forest buffers offset 6.9 MT CO_2e/acre, then if 5% of the available acres for buffers were installed, 4,903 MT CO_2e offset could result.

Riparian conservation/restoration

Assume that the average width of a typical intermittent or perennial stream in Idaho is about 70 feet. Conservation/restoration would include both sides of stream, across the floodplain, wetland area. This would estimate that there are 8.5 acres per mile of stream, a gross estimate.

$$\frac{5280 \text{ ft/mile} \times 70 \text{ ft}}{43560 \text{ ft}^2\text{/acre}}$$ = 8.5 acres per mile stream, across entire floodplain, wetland area. 75% capability of woody species. Use 6 acres per mile.

Utilizing the data generated from intersecting a GIS vegetation (land cover) and land ownership layer through ArcView 2.0, there are 177,588 acres of state and private land riparian/wetland. About 14,280 acres are on state lands, 163,308 on private. Assume that only 50% of those miles are perennial and/or have potential for restoration and adequate available water. Many stream, drains, canals show up within the Hydro100 layer, and are not considered natural streams, therefore will not be considered here for riparian conservation.

Private land riparian areas could offset 0.3 MMT CO_2e, state land nearly 25,000 MMT, utilizing 5.9 MT/acre offset.

Pivot corners

Assume 20 acres per 160 acre pivot (5 acres/corner), or 12.5 % of pivot acres available for plantings. If 640,000 acres is assumed and are available for afforestation (total corner acres), but only 30% are actually afforested, then 84,000 MT CO_2e offset results, based on 5.9 MT CO_2e/acre.

Constructed wetlands

Assume 10 acres per wetland. 10,000 potential acres total for wetlands development. If 75% are developed, then 2,625 MT CO_2e offset results, where 0.35 MT CO2e/acre is used.

13.8 APPENDIX 8 – REFERENCE DATA

REFERENCE DATA – Subject to addition.

practice	attribute	amount	units	mtco2	mtco2/ac/y	area	source	Site
biofuel, grass	biomass	0.16	mtc/ac/y	0.587	0.587	ia	carbon budget for 640 acre farm in iowa	
biofuel, grass	biomass	0.400	mtc/ha/y	1.468	0.594	ia	Iowa farm budget	lal 98
conservation till, from plow	soil carbon	0.16	mtc/ac/y	0.587	0.587	ia	carbon budget for 640 acre farm in iowa	
conservation till, from plow	soil carbon	9.5	Mg c/ha/30y	34.865	0.471	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
conservation tillage, from sage	soil carbon	8.0	Mg c/ha/30y	29.360	0.396	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
cover crops	soil carbon	0.2	mtc/ha/y	0.734	0.297	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
cover crops	soil carbon	0.23-0.34	mtc/ha/y	0.84-1.25	0.34-0.51	usa	donigian et al, 95	www.nrdc.org/globalwarming/psoil.asp?pf=-1
CRP	biomass	0.3-0.7	mtc/ha/y	1.10-2.57	0.44-1.04	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
direct seed	soil carbon	.24-.40	mtc/ha/y	0.88-1.47	0.36-0.60	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
eliminate fallow	biomass	0.09	mtc/ac/y	0.330	0.330	wy	wyoming carbon sequestration report	
eliminate fallow	soil carbon	0.2	mtc/ha/y	0.734	0.297	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
erosion control	soil carbon	0.1-0.3	mtc/ha/y	0.37-1.10	0.15-0.44	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
existing soils carbon	soil carbon	20-61	mtc/ac	73.4-223.9		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forages added	soil carbon	0.2	mtc/ac/y	0.734	0.734	ia	carbon budget for 640 acre farm in iowa	
forested, afforestation	biomass	0.191	mtc/ac/y	0.700	0.700	nc	north carolina sensible ghg reduction strategies	http://www.geo.appstate.edu/bulletin/EPA_projects/NCaction/intro.html
forested, afforestation	biomass	0.204	mtc/ac/y	0.750	0.750	nj	new jersey greenhouse action plan	http://www.epa.gov/globalwarming/publications/actions/state/nj_actionplan.pdf
forested, aspen-birch	biomass	12.03	lb c/ft3	0.020		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, aspen-birch	biomass	14.45	lb c/ft3	0.024		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, aspen-birch	biomass	7.56	mtc/ac	27.745		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, crop to douglas/fir	biomass	6657	lb c/ac/80y	11.082	0.139	pc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to oak-hickory	biomass	3247	lb c/ac/40y	5.405	0.135	se usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to ponerosa pine	biomass	2074	lb c/ac/100y	3.453	0.035	pc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to spruce/fir	biomass	1979	lb c/ac/80y	3.294	0.041	nc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to spruce/fir	biomass	2460	lb c/ac/80y	4.095	0.051	ne usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to white/red pine	biomass	2854	lb c/ac/65y	4.751	0.073	ne usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, crop to white/red pine	biomass	4344	lb c/ac/80y	7.231	0.090	nc usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, elm-ash-cottonwood	biomass	12.03	lb c/ft3	0.020		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, elm-ash-cottonwood	biomass	14.45	lb c/ft3	0.024		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, elm-ash-cottonwood	biomass	5.46	mtc/ac	20.038		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, existing stands	biomass	63.2-65.0	mtc/ac	231.9-238.5		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, forest plantings	biomass	290	lb c/ac/y	0.483	0.483	in	living memorial tree planting program	http://yosemite.epa.gov/globalwarming/ghg.nsf
forested, from crop	biomass	0.750	mtc/ha/y	2.753	1.114	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01
forested, from crop	biomass	2.64	mtc/ac/y	9.689	9.689	il	climate change action for illinois	http://dnr.state.il.us/orep/inrin/eg/iccp/toc.htm
forested, from crop	biomass	13.5	mtc/ac/y	49.545	49.545	ia	iowa GHG action plan	http://www.cgrer.uiowa.edu/research/reports/iggap
forested, from eroded lands	biomass	0.3-0.7	mtc/ha/y	1.10-2.57	0.44-1.04	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99

practice	attribute	amount	units	mtco2	mtco2/ac/y	area	source	Site
forested, from grazed forest	biomass	2.3	mtc/ac/y	8.441	8.441	il	climate change action for illinois	http://dnr.state.il.us/orep/inrin/eg/iccp/toc.htm
forested, from pasture	biomass	2.06	mtc/ac/y	7.560	7.560	il	climate change action for illinois	http://dnr.state.il.us/orep/inrin/eg/iccp/toc.htm
forested, loblolly-shortleafed pine	biomass	13.69	lb c/ft3	0.023		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, loblolly-shortleafed pine	biomass	16.47	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, loblolly-shortleafed pine	biomass	10.46	mtc/ac	38.388		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, maple-beech-birch	biomass	12.09	lb c/ft3	0.020		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, maple-beech-birch	biomass	17.99	lb c/ft3	0.030		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, maple-beech-birch	biomass	7.56	mtc/ac	27.745		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak hickory	biomass	13.52	lb c/ft3	0.023		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak hickory	biomass	19.64	lb c/ft3	0.033		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak hickory	biomass	5.46	mtc/ac	20.038		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak-pine	biomass	13.69	lb c/ft3	0.023		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak-pine	biomass	16.47	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, oak-pine	biomass	10.46	mtc/ac	38.388		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, others	biomass	16.00	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, others	biomass	16.00	lb c/ft3	0.027		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, others	biomass	5.46	mtc/ac	20.038		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, pine	biomass	3757	lb c/ac/30y	6.254	0.208	se usa	hawai climate change action plan	http://www.hawaii.gov/dbedt/ert/ghg_toc.html
forested, pivot corners	biomass	15-29	mtc/ac total	55.1-106.4		neb	quanitifying change in GHG emmisions...in neb.-01	neb-01
forested, plantation	biomass	5.6-7.8	mtc/ha/y	20.5-28.6	8.30-11.58	ia	from Iowa farm budget	colletti 99
forested, ponderosa pine	biomass	1.6	mtc/ac/y	5.872	5.872	id	nez perce tribe - kummett, 02	
forested, ponderosa pine	biomass	1.9	mtc/ac/y	6.973	6.973	id	nez perce tribe - kummett, 02	
forested, reserved forest	biomass	6.51	mtc/ac	23.892		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, riparian buffer	biomass	17.6-35.2	mtc/ac total	64.6-129.2	3.2-6.4	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, enhancement	biomass	7.1	mtc total	26.057	0.651	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, trees/shrubs	biomass	42.9	mtc total	157.443	3.936	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, various types	biomass	0.63	mtc/ac	2.312		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, various types	biomass	22.2	mtc/ac	81.474		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, various types	soil carbon	40.12	mtc/ac	147.240		ia	carbon storage quanitification & methodology demo	http://www.cgrer.uiowa.edu/research/reports/iggap/finalgg3.PDF
forested, windbreak	biomass	3.24	mtc/ac/y	11.891	11.891	ia	carbon budget for 640 acre farm in iowa	
forested, windbreak/shelterbelt	biomass	67.5-135	mtc/ac total	248-495	12.4-24.8	ne	quanitifying change in GHG emmisions...in neb.	neb-01
forested, windbreak/shelterbelt	biomass	15-30	mtc/ac total	55.1-110.1	2.2-5.5	ne	quanitifying change in GHG emmisions...in neb.	neb-01
grass waterways/buffers	biomass	0.13	mtc/ac/y	0.477	0.477	wy	wyoming carbon sequestration report	
grass, from crop	soil carbon	0.3-0.5	mtc/ha/y	1.10-1.83	0.44-0.74	usa	ipcc/oecd	www.nrdc.org/globalwarming/psoil.asp?pf=-1
grazing, prescribed	biomass	0.01	mtc/ha/y	0.037	0.015	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01
grazing, prescribed	biomass	0.1	mtc/ha/y	0.367	0.149	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01
grazing, prescribed	biomass	0.25	mtc/ha/y	0.918	0.371	ne	quanitifying change in GHG emmisions...in neb.-01	neb-01

practice	attribute	amount	units	mtco2	mtco2/ac/y	area	source	Site
grazing, prescribed	biomass	0.13+	mtc/ac/y	0.477+	0.477+	wy	Schuman et al, 1999	wyoming carbon sequestration report
grazing, proper stock rates	biomass	0.13	mtc/ac/y	0.477	0.477	wy	Schuman et al, 1999	wyoming carbon sequestration report
irrigation (sub), on poor soils	soil carbon	0.1	mtc/ha/y	0.367	0.149	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
irrigation, added	soil carbon	0.1	mtc/ha/y	0.367	0.149	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
irrigation, mngt improved	soil carbon	0.02	mtc/ac/y	0.073	0.073	wy	wyoming carbon sequestration report	
mine lands restoration	biomass	1-3	mtc/ha/y	3.67-11.0	1.49-4.45	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
mulch till	soil carbon	0.5	mtc/ha/y	1.835	0.743	ia	from Iowa farm budget	lal, 98
nitrogen fert.-mtn meadows	emmissions	0.300	mtc/ha/y	1.101	0.446	neb	quanitifying change in GHG emmisions...in neb.-01	neb-01
no til & cover crop	soil carbon	0.09	mtc/ac/y	0.330	0.330	wy	wyoming carbon sequestration report	
no till	soil carbon	0.09	mtc/ac/y	0.330	0.330	wy	wyoming carbon sequestration report	
no-till	soil carbon	0.14	mtc/ha/y	0.514	0.208	mid-w	buyanovsky, wagner, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
no-till	soil carbon	0.14	mtc/ha/y	0.514	0.208	usa	grant et al, 97	www.nrdc.org/globalwarming/psoil.asp?pf=-1
no-till	soil carbon	0.5	mtc/ha/y	1.835	0.743	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
no-till N2O field emission	emmissions	0.050	mt co2/ac/y	0.050	0.050	ia	iowa integrated farm mngt demo proj.	http://extension.agron.iastate.edu/soils
no-till C diesel emission	emmissions	6.5-13	lbs c/ac/y	.01-.02	.01-.02	ia	iowa integrated farm mngt demo proj.	http://extension.agron.iastate.edu/soils
no-till	soil carbon	0.3-0.5	mtc/ha/y	1.10-1.83	0.44-0.74	ia	from Iowa farm budget	bruce, 99
no-till, residue mngt	soil carbon	0.15	mtc/ac/y	0.551	0.551	id-wa	PNDSA-ENTERGY agreement	
nutrient management	soil carbon	0.1	mtc/ha/y	0.367	0.149	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
nutrient management	soil carbon	.09-.22	mtc/ac/y	0.33-0.81	0.33-0.81	wy	wyoming carbon sequestration report	
nutrient management	emmissions	0.15-0.50	mtc/ha/y	0.55-1.83	0.22-0.74	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
nutrient management N2O	emmissions	0.050	mtc/ac/y	0.050	0.050	ia	reducing nitrogen fertilizer use	http://yosemite.epa.gov/globalwarming/ghg.nsf/CaseStudiesNew/Reducing+Nitrogen+Fertilizer+Use+(Iowa)/$file/IA_reduce.pdf
nutrient management CO2 diesel	emissions	0.039	mtco2/ac/y	0.039	0.039	ia	iowa integrated farm mngt demo proj.	http://extension.agron.iastate.edu/soils
pasture (irr.) from sage	soil carbon	3.56	Mg c/ha/30y	13.065	0.176	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
pasture, from crop	soil carbon	0.75-1.0	mtc/ha/y	2.75-3.67	1.11-1.48	usa	tyson et al, 90, haynes et al, 91	www.nrdc.org/globalwarming/psoil.asp?pf=-1
pasture, from plow	soil carbon	3.71	Mg c/ha/30y	13.616	0.184	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
permanent cover, from crop	biomass	0.13	mtc/ac/y	0.477	0.477	wy	wyoming carbon sequestration report	
residue mngt, type?	soil carbon	0.18	mtc/ha/y	0.661	0.267	usa	lal et al, 98	www.nrdc.org/globalwarming/psoil.asp?pf=-1
ridge till	soil carbon	0.05	mtc/ac/y	0.184	0.184	wy	wyoming carbon sequestration report	
sage brush, from plow	soil carbon	0.15	Mg c/ha/30y	0.551	0.007	id	entry, et al, 2002	soil sci soc am j 66:1957-1964 (2002)
sawdust & nitrogen	soil carbon	0.35	mtc/ha/y	1.285	0.520	usa	paustian et al, 92	www.nrdc.org/globalwarming/psoil.asp?pf=-1
straw incorporated	soil carbon	0.33	mtc/ha/y	1.211	0.490	can	paustian et al, 96	www.nrdc.org/globalwarming/psoil.asp?pf=-1
summer fallow elimination	biomass	0.1-0.3	mtc/ha/y	0.37-1.10	0.15-0.44	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99
switchgrass, from crop	biomass	0.3	mtc/ac/y	1.101	1.101	ia	iowa GHG action plan	http://www.cgrer.uiowa.edu/research/reports/iggap
wetland restoration	biomass	0.250	mtc/ha/y	0.918	0.371	ia?	from Iowa farm budget	lal 98
WRP	biomass	.15-.35	mtc/ha/y	0.55-1.28	0.22-0.52	usa	swcs-ji-99, managing us cropland to sequester…	swcs-J1-99